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*MATHÉMATIQUES*

# DÉFORMATION D'UNE SURFACE AU VOISINAGE D'UN POINT PARABOLIQUE

Par N. EFIMOV

*(Présenté par A. N. Kolmogoroff, de l'Académie, le 20. VIII. 1939)*

Dans une Note précédente (1) nous avons étudié certains invariants arithmétiques d'un point régulier parabolique d'une surface analytique. Pour l'un de ces invariants—l'indice (ind) du point parabolique (1)—nous avons signalé les propriétés suivantes:

1) Si l'ordre de contact de la surface avec un plan tangent au point parabolique $M_0$ est égal à 1 et si ce point $M_0$ a un indice déterminé, les seules valeurs possibles pour l'indice sont les nombres $-1$, 0, $+1$.

2) Il existe pour chaque surface $U$, avec un point parabolique $M_0$, une surface isométrique $U'$, qui est en contact du premier ordre avec le plan tangent au point $M_0'$ correspondant à $M_0$; donc, l'indice de ce point a l'une des trois valeurs: $-1$, 0, $+1$ si toutefois il est déterminé.

Parmi ces surfaces $U'$ il y en a une infinité ayant au point parabolique $M_0'$ un indice déterminé *, ce que résulte du théorème suivant:

Si $M_0$ est un point parabolique de la surface $U$ et si $t$ est une direction arbitraire au point $M_0$, il existe une surface $U'$ isométrique à $U$, dont l'ordre de contact avec le plan tangent au point $M_0'$ correspondant au point $M_0$ est égal à un, et pour laquelle la direction $t'$ correspondant à $t$ est asymptotique.

On se demande, tout naturellement, si la valeur de l'indice du point parabolique est la même pour toutes les surfaces $U'$ qui viennent d'être ainsi déterminées. Nous avons résolu ce problème en excluant une certaine classe particulière de surfaces.

Soit $S(u, v)$ une multiplicité riemannienne à deux dimensions, dont l'élément linéaire

$$ds^2 = Edu^2 + 2Fdu\,dv + Gdv^2$$

a les coefficients $E$, $F$, $G$ réguliers au voisinage du point $u=0$, $v=0$. En désignant la courbure totale par $K(u, v)$ et en supposant $K(0, 0)=0$, nous bornons notre classe de multiplicités $S(u, v)$, en admettant que parmi les branches de la courbe $K(u, v)=0$, qui passent par le point $u=0$, $v=0$, il n'y a pas de géodésiques. Nous avons alors le théorème suivant:

Théorème. *Quelle que soit la multiplicité $S(u, v)$, toutes les surfaces de l'espace euclidien à trois dimensions isométriques à $S(u, v)$, dont*

* Nous n'analysons pas les surfaces dont la courbure totale est identiquement nulle.

*l'ordre du contact avec le plan tangent au point parabolique* $u=0$, $v=0$ *est égal à un, ont en ce point le même indice; les valeurs de cet indice* $-1$, $0$, *ou* $+1$ *ne dépendent ainsi que de la métrique de la surface.*

Ce théorème constate, évidemment, que toutes les multiplicités $S(u, v)$ se divisent en trois catégories, et qu'à chaque catégorie correspond une forme précise de réalisation de la multiplicité $S(u, v)$ en forme de surface $U$ de l'espace euclidien, ayant un contact du premier ordre avec un plan tangent au point parabolique $M_0(u=0, v=0)$ et un indice déterminé en ce point.

Notamment:

1) ind $M_0=+1$; la surface $U$ au point $M_0$ est convexe (bien qu'il peut exister dans chaque voisinage de $M_0$ des points avec une courbure totale négative).

2) ind $M_0=-1$; la surface $U$ près de $M_0$ est en forme d'une selle.

3) ind $M_0=0$; la surface $U$ est analogue à une surface de rotation dont le méridien a un point d'inflexion.

A chacune de ces trois formes de la surface $U$ correspond, inversement, une géométrie intrinsèque caractéristique.

Il suit des théorèmes, formulés dans la Note [1], qu'au cours d'une déformation continue du voisinage d'un point parabolique son indice en général ne change pas. Dans le cas, où la surface est en contact d'ordre $p>2$ avec le plan tangent au point parabolique, l'indice ne varie pas au cours des déformations continues, parce que la déformation infiniment petite est un infiniment petit d'ordre supérieur; d'ailleurs, sauf quelques rares exceptions, l'ordre de la déformation infiniment petite croît avec $p$. Nous donnerons des énoncés exacts dans quelques théorèmes ci-dessous, qui permettent d'ailleurs d'éclairer quelques sources algébriques des faits mentionnés.

$U(M_0)$ désignera ici et dans la suite un voisinage arbitraire du point parabolique $M_0$ de la surface $U$; $\tau$—le plan tangent au point $M_0$; $p$—l'ordre de contact de $U$ avec $\tau$.

Si l'on choisit le système cartésien orthogonal de coordonnées $x$, $y$, $z$ ayant l'origine au $M_0$ et les axes $x$, $y$ dans le plan $\tau$, alors $U(M_0)$ se déterminera par l'équation

$$z=f^{(p+1)}(x, y)+f^{(p+2)}(x, y)+\ldots, \tag{1}$$

où $f^{(m)}(x, y)$ est une forme homogène de degré $m$.

Nous donnerons à la surface

$$z=f^{(p+1)}(x, y)+f^{(p+2)}(x, y)+\ldots+f^{(p+k)}(x, y) \tag{2}$$

le nom d'un paraboloïde osculateur d'ordre $p+k$, et nous la désignons par $P_m(M_0)$ $(m=p+k)$.

Soit

$$f^{(p+1)}(x, y)=a_0x^{p+1}+\binom{p+1}{1}a_1x^p y+\ldots+a_{p+1}y^{p+1}; \tag{3}$$

considérons la matrice

$$A=\begin{Vmatrix} a_0 & a_1 & a_2 & \ldots & a_{p-1} \\ a_1 & a_2 & a_3 & \ldots & a_p \\ a_2 & a_3 & a_4 & \ldots & a_{p+1} \end{Vmatrix} \tag{4}$$

de rang $R(A)$. Nous avons alors le théorème suivant.

Théorème A. *Si la forme* $f^{(p+1)}(x, y)$ *n'a pas de facteurs linéaires multiples (réels) et* $R(A)=3$, *l'ordre* $p$ *reste invariant au cours de chaque*

*déformation continue de la surface $U(M_0)$ et le paraboloïde osculateur $P_{p+1}(M_0)$ ne subit aucune déformation* *.

Supposons maintenant, que $F(x, y)$ est une forme homogène de degré $m$. En désignant par $A$ la matrice qui est construite pour $F(x, y)$ de même que la matrice (4) pour $f^{(p+1)}(x, y)$, supposons que $R(A)=3$. Considérons maintenant toutes les formes homogènes $\Phi(x, y)$ de degré $n>m$ qui satisfont à l'identité:

$$F_{yy}\Phi_{xx} - 2F_{xy}\Phi_{xy} + F_{xx}\Phi_{yy} \equiv 0. \tag{5}$$

Nous déterminerons le nombre $N(F)$ par la condition suivante: $N(F)=k$, si toutes les formes $\Phi(x, y)$ de degré $n=m+1, m+2, \ldots, m+k$ sont identiquement nulles et s'il existe une forme $\Phi(x, y)$ de degré $n=m+k+1$.

Note. Si $K(A)<3$, il existe alors une forme $\Phi(x, y)$ d'une puissance quelconque, satisfaisant à l'identité (5). Il existe, d'ailleurs, des formes $f(x, y)$ de degré $m$ avec $N(f)=m-3$. C'est, par exemple, la forme $f(x, y)=x^m+mxy^{m-1}$.

Théorème B. *Supposons que les surfaces $U(M_0)$ et $U'(M_0)$ sont déterminées par les équations*:

$$z=F^{(m)}(x, y)+F^{(m+1)}(x, y)+\ldots$$

*et*

$$z=F^{(m)}(x, y)+\Phi^{(m+1)}(x, y)+\ldots \quad (m\geqslant 4)$$

*où $F^{(k)}(x, y)$ et $\Phi^{(k)}(x, y)$ sont des formes homogènes. Si $U(M_0)$ et $U'(M_0)$ sont isométriques, alors*

$$\Phi^{(m+k)}(x, y) \equiv F^{(m+k)}(x, y)$$

*où $k=1, 2, \ldots N(F^{(m)})$.*

Si dans chaque déformation continue de la surface $U(M_0)$ le paraboloïde osculateur $P_m(M_0)$ ne subit aucune déformation, nous appellerons le nombre $m-p$ l'ordre d'indéformabilité relative à la surface $U(M_0)$.

Il suit de ces deux théorèmes A et B

Théorème C. *Supposons que la surface $U(M_0)$ est déterminée par l'équation*

$$z=f^{(m)}(x, y)+f^{(m+1)}(x, y)+\ldots$$

*alors, si la forme homogène $f^{(m)}(x, y)$ n'a pas de facteurs linéaires multiples (réels) et l'identité (4) détermine pour elle une matrice $A$ de rang 3, la surface $U(M_0)$ a un ordre d'indéformabilité relative $h \geqq N(f^{(m)})$.*

Il résulte de ce théorème et de la note qui suit le théorème A, qu'il existe une surface ayant un ordre d'indéformabilité relative qui est positif et arbitrairement grand.

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LITTÉRATURE CITÉE

[1] N. Efimov, C. R. Acad. Sci. URSS, XXIII, No. 9 (1939).

* Nous supposons ici et dans la suite, que le premier membre de l'équation de la surface déformée et ses dérivées partielles par rapport aux coordonnées $x, y, z$ jusqu'à l'ordre $p+1$ sont des fonctions continues du paramètre de la déformation.

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*THÉORIE DE L'ÉLASTICITÉ*

# DÉFORMATION PLANE GÉNÉRALISÉE DANS UN CORPS INFINI ANISOTROPE ÉLASTIQUE LIMITÉ PAR LA SURFACE D'UN CYLINDRE PARABOLIQUE

Par S. LEKHNITSKY

*(Présenté par S. L. Soboleff, de l'Académie, le 29. VI. 1939)*

1. Considérons le problème sur la distribution des tensions dans un corps infini homogène et anisotrope limité par la surface d'un cylindre parabolique; ce corps est déformé par des efforts extérieurs distribués sur la surface cylindrique.

Supposons que 1) le corps suit la loi de Hook sous sa forme la plus générale; 2) les efforts extérieurs n'ont pas de projections sur la direction des génératrices et ne varient pas le long de la génératrice; 3) il n'y a pas d'efforts de volume; 4) les déformations sont petites.

Prenons une section quelconque, normale à la génératrice, pour le plan $XOY$; on obtient sur le plan $XOY$ le domaine $S$ extérieur à la parabole. Dirigeons les axes $OX$, $OY$ de manière que l'équation du contour $L$ du domaine $S$ ait la forme:

$$y = ax^2 \quad (a > 0) \tag{1.1}$$

ou sous la forme paramétrique:

$$x = t, \quad y = at^2 \cdot (-\infty < t < \infty). \tag{1.2}$$

Un corps isotrope dans ces conditions éprouve une déformation plane (relativement au plan $XOY$). Un corps anisotrope avec anisotropie générale éprouve la déformation d'un type plus général: les projections de déplacement sont seulement les fonctions des $x, y$, mais $w=0$. Nous appelons la déformation de ce type—déformation plane généralisée. Dans le cas particulier la déformation sera plane s'il y a des relations entre les constantes élastiques (1).

N. Mouskhélichvili, membre de l'Académie, a donné la méthode de la solution du problème plan (pour un corps isotrope) pour les domaines semi-infinis, basée sur l'application des intégrales analogues à celles de Cauchy. Dans le cas particulier il a obtenu la solution du problème pour le domaine extérieur à la parabole(2). La méthode de Mouskhélichvili peut être appliquée à notre problème.

2. Dans le cas de la déformation plane généralisée les formules générales suivantes sont obtenues pour les tensions (3):

$$\left.\begin{aligned}
\sigma_x &= 2Re\,[\mu_1^2\Phi_1'(z_1) + \mu_2^2\Phi_2'(z_2) + \mu_3^2\lambda_3\Phi_3'(z_3)],\\
\sigma_y &= 2Re\,[\Phi_1'(z_1) + \Phi_2'(z_2) + \lambda_3\Phi_3'(z_3)],\\
\tau_{xy} &= -2Re\,[\mu_1\Phi_1'(z_1) + \mu_2\Phi_2'(z_2) + \mu_3\lambda_3\Phi_3'(z_3)],\\
\tau_{xz} &= 2Re\,[\mu_1\lambda_1\Phi_1'(z_1) + \mu_2\lambda_2\Phi_2'(z_2) + \mu_3\Phi_3'(z_3)],\\
\tau_{yz} &= -2Re\,[\lambda_1\Phi_1'(z_1) + \lambda_2\Phi_2'(z_2) + \Phi_3'(z_3)];
\end{aligned}\right\} \tag{2.1}$$

$$\sigma_z = -\frac{1}{a_{33}}(a_{13}\sigma_x + a_{23}\sigma_y + a_{34}\tau_{yz} + a_{25}\tau_{xz} + a_{36}\tau_{xy}) \qquad (2.2)$$

où $a_{ij}$ sont les constantes élastiques des équations de la loi généralisée de Hook,

$$\lambda_k,\ \mu_k = \alpha_k + i\beta_k \quad (k = 1, 2, 3, \quad \beta_k > 0)$$

sont les quantités complexes qui dépendent des constantes élastiques, $\Phi_k(z_k)$ sont les fonctions analytiques des variables complexes $z_k = x + \mu_k y$. Sur la surface cylindrique ou sur le contour $L$ nous avons les conditions

$$\left.\begin{aligned} &\sigma_x \cos(n, x) + \tau_{xy}\cos(n, y) = X_n, \\ &\tau_{xy}\cos(n, x) + \sigma_y \cos(n, y) = Y_n, \\ &\tau_{xz}\cos(n, x) + \tau_{yz}\cos(n, y) = 0, \end{aligned}\right\} \qquad (2.3)$$

où $n$ est la direction de la normale extérieure, $X_n$, $Y_n$ sont les projections des efforts extérieurs sur l'unité de surface.

Introduisons des variables nouvelles

$$x_k = x + \alpha_k y, \quad y_k = \beta_k y. \qquad (2.4)$$

Alors

$$z_k = x_k + iy_k \quad (k = 1, 2, 3).$$

Le problème se réduit à la détermination de trois fonctions holomorphes dans les domaines $S_k$ sur les plans $z_k$ obtenus de $S$ à l'aide des transformations (2.4). Ces domaines sont extérieurs aux paraboles:

$$x_k = t + \alpha_k at^2, \quad y_k = \beta_k at^2 \qquad (2.5)$$

[$t$ est le même paramètre que celui de l'équation (1.2)].

Introduisons des conditions complémentaires:

1) Le vecteur principal des efforts extérieurs $X_n$, $Y_n$ sur un segment quelconque du contour tend vers une limite définie, quand la longueur du segment croît indéfiniment; 2) l'expression

$$\Delta = \mu_1 - \mu_2 + \lambda_2\lambda_3(\mu_3 - \mu_1) + \lambda_1\lambda_3(\mu_2 - \mu_3) \neq 0. \qquad (2.6)$$

A cause de la première condition complémentaire pour les $|z_k|$ assez grands nous aurons

$$\Phi_k'(z_k) = 0\left(\frac{1}{z_k}\right). \qquad (2.7)$$

3. On peut donner la représentation conforme des domaines $S$, $S_k$ sur le semi-plan inférieur $\eta \leqslant 0$ de manière qu'au point $t$ sur le contour du semi-plan correspondent les points sur les contours $L$, $L_k$ des domaines $S$, $S_k$ avec les coordonnées (1.2), (2.5). Les fonctions qui donnent cette représentation conforme sont

$$z = \zeta + ia\zeta^2, \qquad (3.1)$$

$$z_k = \zeta_k + \mu_k a\zeta_k^2 \qquad (3.2)$$

($\zeta$, $\zeta_k$ sont les points dans le semi-plan inférieur).

Les expressions inverses sont:

$$\zeta(z) = \frac{\sqrt{1 + 4aiz} - 1}{2ia}, \qquad (3.3)$$

$$\zeta_k(z_k) = \frac{\sqrt{1 + 4a\mu_k z_k} - 1}{2\mu_k a}. \qquad (3.4)$$

Pour les points sur $L$, $L_k$

$$\zeta = \zeta_k = t.$$

Posons

$$\Phi_k(z_k) = \Phi_k(\zeta_k + \mu_k a\zeta_k^2) = \Psi_k(\zeta_k). \tag{3.5}$$

Alors

$$\Phi_k'(z_k) = \frac{\Psi_k'(\zeta_k)}{1 + 2a\mu_k\zeta_k} = \frac{\Psi_k'(\zeta_k)}{\sqrt{1 + 4a\mu_k z_k}}. \tag{3.6}$$

Les conditions (2.3) peuvent être écrites sous la forme:

$$\left.\begin{aligned}
\mu_1\Psi_1'(t) + \mu_2\Psi_2'(t) + \mu_3\lambda_3\Psi_3'(t) + \\
+\overline{\mu}_1\overline{\Psi}_1'(t) + \overline{\mu}_2\overline{\Psi}_2'(t) + \overline{\mu}_3\overline{\lambda}_3\overline{\Psi}_3'(t) = -X_n(t)\sqrt{1+4a^2t^2}, \\
\Psi_1'(t) + \Psi_2'(t) + \lambda_3\Psi_3'(t) + \\
+ \overline{\Psi}_1'(t) + \overline{\Psi}_2'(t) + \overline{\lambda}_3\overline{\Psi}_3'(t) = Y_n(t)\sqrt{1+4a^2t^2}, \\
\lambda_1\Psi_1'(t) + \lambda_2\Psi_2'(t) + \Psi_3'(t) + \\
+\overline{\lambda}_1\overline{\Psi}_1'(t) + \overline{\lambda}_2\overline{\Psi}_2'(t) + \overline{\Psi}_3'(t) = 0,
\end{aligned}\right\} \tag{3.7}$$

où $\overline{\mu}_k$, $\overline{\lambda}_k$, $\overline{\Psi}_k'(t)$ sont les valeurs conjuguées avec $\mu_k$, $\lambda_k$, $\Psi_k'(t)$.

Multiplions les deux parties des équations (3.7) par $\frac{1}{2\pi i}\frac{dt}{t-\zeta}$, où $t$ est le point du semi-plan inférieur, et intégrons de $-\infty$ à $+\infty$. Alors nous aurons (4):

$$\left.\begin{aligned}
\mu_1\Psi_1'(\zeta) + \mu_2\Psi_2'(\zeta) + \mu_3\lambda_3\Psi_3'(\zeta) = \frac{1}{2\pi i}\int_{-\infty}^{\infty}\frac{X_n\sqrt{1+4a^2t^2}}{t-\zeta}\,dt, \\
\Psi_1'(\zeta) + \Psi_2'(\zeta) + \lambda_3\Psi_3'(\zeta) = -\frac{1}{2\pi i}\int_{-\infty}^{\infty}\frac{Y_n\sqrt{1+4a^2t^2}}{t-\zeta}\,dt, \\
\lambda_1\Psi_1'(\zeta) + \lambda_2\Psi_2'(\zeta) + \Psi_3'(\zeta) = 0.
\end{aligned}\right\} \tag{3.8}$$

Il suit

$$\left.\begin{aligned}
\Psi_1'(\zeta) = \frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(1-\lambda_2\lambda_3) + Y_n(\mu_2 - \mu_3\lambda_2\lambda_3)}{t-\zeta}\sqrt{1+4a^2t^2}\,dt, \\
\Psi_2'(\zeta) = \frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(\lambda_1\lambda_3 - 1) + Y_n(\mu_3\lambda_1\lambda_3 - \mu_1)}{t-\zeta}\sqrt{1+4a^2t^2}\,dt, \\
\Psi_3'(\zeta) = \frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(\lambda_2 - \lambda_1) + Y_n(\mu_1\lambda_2 - \mu_2\lambda_1)}{t-\zeta}\sqrt{1+4a^2t^2}\,dt;
\end{aligned}\right\} \tag{3.9}$$

$$\left.\begin{aligned}
\Phi_1'(z_1) = \frac{1}{\sqrt{1+4a\mu_1 z_1}}\cdot\frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(1-\lambda_2\lambda_3) + Y_n(\mu_2 - \mu_3\lambda_2\lambda_3)}{t-\zeta_1(z_1)}\sqrt{1+4a^2t^2}\,dt \\
\Phi_2'(z_2) = \frac{1}{\sqrt{1+4a\mu_2 z_2}}\cdot\frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(\lambda_1\lambda_3 - 1) + Y_n(\mu_3\lambda_1\lambda_3 - \mu_1)}{t-\zeta_2(z_2)}\sqrt{1+4a^2t^2}\,dt \\
\Phi_3'(z_3) = \frac{1}{\sqrt{1+4a\mu_3 z_3}}\cdot\frac{1}{2\pi i\Delta}\int_{-\infty}^{\infty}\frac{X_n(\lambda_2 - \lambda_1) + Y_n(\mu_1\lambda_2 - \mu_2\lambda_1)}{t-\zeta_3(z_3)}\sqrt{1+4a^2t^2}\,dt.
\end{aligned}\right\} \tag{3.10}$$

Si $a=0$, nous obtenons la solution pour le corps infini limité par un plan $y=0$ *.

Dans le cas particulier pour $\lambda_1=\lambda_2=\lambda_3=0$ nous obtenons la solution du problème plan (pour le cas de déformation plane):

$$\left.\begin{aligned}
\Phi_1'(z_1)&=\frac{1}{\sqrt{1+4a\mu_1 z_1}}\cdot\frac{1}{2\pi i(\mu_1-\mu_2)}\int_{-\infty}^{\infty}\frac{X_n+\mu_2 Y_n}{t-\zeta_1(z_1)}\sqrt{1+4a^2t^2}\,dt,\\
\Phi_2'(z_2)&=-\frac{1}{\sqrt{1+4a\mu_2 z_2}}\cdot\frac{1}{2\pi i(\mu_1-\mu_2)}\int_{-\infty}^{\infty}\frac{X_n+\mu_1 Y_n}{t-\zeta_2(z_2)}\sqrt{1+4a^2t^2}\,dt,\\
\Phi_3'(z_3)&=0.
\end{aligned}\right\}\qquad(3.11)$$

Les tensions se déterminent d'après les formules (2.1)—(2.2).

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Université Tschernychevsky à Saratov.

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* Il faut comprendre les intégrales (3. 10) comme valeurs principales.

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*MECHANICS*

# A TENSOMETER FOR DETERMINING THE TENSOR OF STRESSES

By W. MAISEL

*(Communicated by N. I. Muskhelishvili, Member of the Academy, 7. VIII. 1939)*

The object of the present article is to set forth the results of our work carried out during the period of 1936—1939* and concerned with the development of a tensometer capable of determining the whole tensor of strains (deformations) in a direct manner, and hence the whole tensor of stresses produced upon the surface of the bodies subjected to deformations.

Suppose the body $M$ to be free from any applied load; let us then denote through $\overline{1}$, $\overline{2}$, $\overline{3}$ (Fig. 1) three points upon the surface of the body in question, these points being arranged in such a way that $\overline{12}=\overline{13}=\overline{23}$. Assume that these bases $\overline{12}$, $\overline{13}$, $\overline{23}$ (or the sides of the triangle $\overline{1}\,\overline{2}\,\overline{3}$) are sufficiently small, so that the element $\overline{1}\,\overline{2}\,\overline{3}$ of the surface might be considered as plane. Let us draw through the center of gravity $O$ of the triangle $\overline{1}\,\overline{2}\,\overline{3}$ the co-ordinate axes $Ox$ (coinciding with the direction $\overline{0}\,\overline{1}$) and $Oy$ (parallel to $\overline{2}\,\overline{3}$).

If afterwards a given load is applied to the body $M$, the above points $\overline{1}$, $\overline{2}$, $\overline{3}$ will shift into new positions.

Assuming that no load is applied at the point $O$, we obtain directly from the fundamental formula, as used in the theory of elasticity for the deformation of a rectilinear element passing through the point $O$, the following expression:

$$\left.\begin{aligned} e_{xx} &= \frac{2}{3}(e_{12}+e_{13}+e_{23})-e_{23}; \quad e_{yy}=e_{23}; \\ e_{xy} &= \frac{2}{\sqrt{3}}(e_{13}-e_{12}) \end{aligned}\right\} \qquad (1)$$

(where $e_{12}$, $e_{13}$, $e_{23}$ are relative elongations of the sides $\overline{12}$, $\overline{13}$, $\overline{23}$).

According to Hook's law for stresses in elastic equilibrium, we have (assuming that $E$ and $\nu$ are Young's and Poisson's moduli respectively, while $\sigma_1$ and $\sigma_2$ are the main stresses):

$$X_x=\frac{E}{1-\nu^2}(e_{xx}+\nu e_{yy}); \quad Y_y=\frac{E}{1-\nu^2}(e_{yy}+\nu e_{xx}); \quad X_y=\frac{E}{1-\nu^2}\left(\frac{1-\nu}{2}\right)e_{xy}. \qquad (2)$$

* Preliminary reports were made at the meetings of the Section of Mechanics of the Institute of Mathematics and Mechanics of the State University of Kharkov, 1936; of the House of Technics of Kharkov 1938; of the Technical Section of the Ukrainian Academy of Sciences, 1938, 1939; of the scientific conferences of the State University of Kharkov and the Building Institute of Kharkov, 1939.

$$\sigma_{1,2} = \frac{1}{2}(X_x + Y_y) \pm \frac{1}{2}\sqrt{(X_x - Y_y)^2 + 4X_y^2}; \quad \operatorname{tg} 2(\sigma_{1,2}, x) = \frac{2X_y}{X_x - Y_y} \qquad (2')$$

$$\sigma_1 + \sigma_2 = \frac{2E}{3(1-\nu)}(e_{12} + e_{13} + e_{23}). \qquad (2'')$$

For a plastic equilibrium (taking the volumetric expansion equal to zero), we have, according to the theory of Mieses-Hencky ($\varepsilon_1$, $\varepsilon_2$, $\varepsilon_3$, being the principal deformations, and $\sigma_s$, the yield point):

$$\left.\begin{aligned} \varepsilon_{1,2} &= \frac{1}{3}(e_{12} + e_{13} + e_{23}) \pm \frac{\sqrt{2}}{3}\sqrt{(e_{12} - e_{13})^2 + (e_{12} - e_{23})^2 + (e_{13} - e_{23})^2} \\ \varepsilon_3 &= -\frac{2}{3}(e_{12} + e_{13} + e_{23}) \end{aligned}\right\} \qquad (3)$$

where

$$\left.\begin{aligned} \sigma_1 &= m(\varepsilon_1 - \varepsilon_3), \qquad \sigma_2 = m(\varepsilon_2 - \varepsilon_3) \\ m &= \frac{\sqrt{2}\sigma_s}{\sqrt{(\varepsilon_1 - \varepsilon_2)^2 + (\varepsilon_1 - \varepsilon_3)^2 + (\varepsilon_2 - \varepsilon_3)^2}} \end{aligned}\right\} \qquad (3')$$

In contradistinction to the usual tensometers which measure the elongation in one direction only, the three-component tensometer proposed by the author (and finally developed in several modifications in collaboration with A. S. Derenkovsky) has been designed with the purpose of measuring the elongations $e_{13}$, $e_{13}$, $e_{23}$ in three directions $\overline{1}\ \overline{2}$, $\overline{1}\ \overline{3}$, $\overline{2}\ \overline{3}$; having determined the values $e_{12}$, $e_{13}$, $e_{23}$ by means of the above instrument, we proceed to calculate the components of the tensor of deformations, by means of formula (1). In the case when we have to do with an elastic equilibrium, the tensor of stresses may be determined by means of the formulae (2) or (2′); while for the case of plastic equilibrium the tensor of stresses will be determined from the formulae (3) and (3′). For determining whether the deformation is elastic or plastic the plastic condition is made use of.

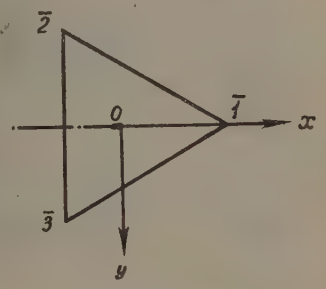

Fig. 1.

A scheme of the proposed instrument is shown in Fig. 2. Referring the reader for its details to the corresponding patent paper, we give here only a short description of the instrument in question.

The latter presents a combined optical and mechanical system; the first consists of a microscope *A* provided with a micrometric scale, which is shown in Fig. 2 and is shaped as an triangle inscribed into a circle, the segments being graduated as a micrometric scale, along the sides of the triangle. The microscope is fixed over the tensometer in such a way, that the center lines of the three radial slots formed between plates *1* are perpendicular to the corresponding sides of the triangle, which are provided with the above-mentioned scales. In this way, the sizes of all three slots can be measured simultaneously in the optical field of the microscope (by means of a micrometric scale) on the diaphragm of the eyepiece.

Three small levers *5* are interconnected by means of an elastic plate *14*, the center of which is clamped between two star-shaped splice plates *12* and *10* by means of screw *6*, while the ends are fixed in teeth *10* and *8* by means of cover-plates *13* and *17* and screws *15*. Each of the three sections of the plate *14* between the teeth *10* and *8* and the central part clamped between *12* and *19* is liable to flexure and twisting simultaneously, owing to the X-sha-

ped form (viewed in plan) of its free, non-fixed part. These flexure and twisting take place about axes running in the plane of the plate in question and intersecting in a point where the vertices of the right angles formed by the outlines of the teeth (viewed in plan) *10* and *8* and the vertices of the right angles formed by the outlines of the star-shaped splice plates *12* and *19* are joined.

In this way, owing to the fact that each of the teeth *10* and *8* is capable of independent (small) rotations about two axes forming right angles in the plane of the plate *14*, while intersecting in a point where the teeth *10* and *8* meet the central splice plates *12* and *19* respectively, each tooth is connected with those splice plates by means of special elastic joint with two degrees of freedom. Therefore the vertices of the teeth, which rest upon the surface of the body under test, will follow all the shifts of their points of contact with the surface of the body during the deformation of the latter. The points where the teeth meet the central splice plates *12* and *19* on the level of the plate *14* have their relative positions unchanged, thanks to the plate.

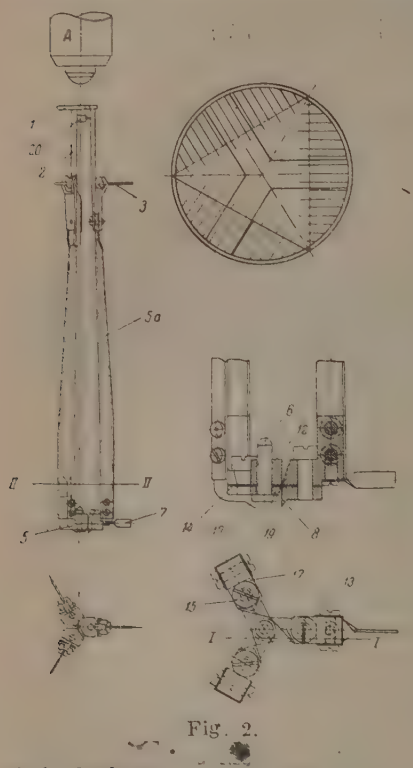

Fig. 2.

From the above said it is evident that each of the teeth *10* and *8* with the attached hollow lever *5 a* (of duraluminium), at the upper end of which plate *1* is fixed by means of the rod *2*, presents a lever of the first class with its fulcrum located upon plate *14*, the lever being able to move in space about its fulcrum.

The result is that the relative location of the plate *1* reprod uces the relative location of the ends of teeth *10* or *8* which are in contact with the surface of the body to be tested. Thus, for example the mutual approach of two ends touching the surface of the given body will cause, as a result of its deformation, the widening of slot between plates *1*, connected by means of levers *5* and *5a* with the corresponding ends.

It follows that the changes in the width of the three slots between the three plates *1*, as measured by means of the scale of microscope *A*, afford the possibility to calculate the deformations of the sides of an equilateral triangle upon the surface of a given body, since the points of the teeth are located in the vertices of the triangle.

Such an instrument has been developed by the authors at the Mechanical Laboratory of the Kharkov State University. The accuracy of its readings is up to twenty thousandths of a millimeter. The instrument has been demonstrated at a meeting of the Technical Section of the Ukrainian Academy of Sciences, July 2, 1938.

During the period of 1938—1939 a new type of the «three-component tensometer» has been developed by the same authors. The precision attained here is so high as to record 1 200 000 of a mm, while

the dimensions of this instrument, as compared with the preceding type, are reduced considerably; the basis measures 3.5 mm. This instrument has been demonstrated at a meeting of the Technical Section of the Ukrainian Academy of Sciences, July 27, 1939.

The methods of handling the «three-component tensometer» and the results obtained in solving experimentally some particular problems of the theory of elasticity and theory of plasticity, will be published in a separate paper, now in preparation.

In conclusion we think fit to point out some particulars of the method suggested.

1. The instrument makes it possible directly and experimentally to record the entire tensor of deformations (and hence the whole tensor of stresses) upon the surface of two-and three-dimensional bodies. Thereby the problems of the elasticity theory concerning plane stressed conditions (and accordingly the plane problem) are completely solved. Having quite an independent importance, the method suggested may also be combined with an optical one, considering its utmost simplicity in determination of the sum of the principal stresses (see formulae 2″).

As far as space problems are concerned, the solution in many cases (thin, plates, shell, envelopes etc.)* is practically obtained by completely determining the deformations and stresses upon the surface of the body deformed.

2. The instrument can be used for studying both elastic and non-elastic deformations.

3. The experimentation can be carried out not only on models, but on finished constructions as well. When experimenting with models, the latter are to be made of the same material as the constructions themselves.

4. The instrument is very simple, while the mode of experimentation is easy and does not require much training.

It appears therefore that the proposed instrument (in its two designs of the industrial and the laboratory type) will receive wide practical application and can be expected to bring experimental solution of a series of problems pertaining to the theory of elasticity and the theory of plasticity.

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* If stresses within the body are to be determined, we can resort to the calculation method (after determining the stresses and deformation on the surface of the body by means of the proposed tensometer) or to use the proposed tensometer in combination with the «freezing» method.

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*MECHANICS*

# DETERMINATION OF STRESSES IN A STRIP WITH A ROUND HOLE, SUBJECTED TO TENSION, BY MEANS OF A TENSOMETER, RECORDING THE PRINCIPAL STRESSES AND THEIR DIRECTIONS

By W. MAISEL

*(Communicated by N. I. Muskhelishvili, Member of the Academy, 7. VIII. 1939)*

In the present article are reported some data obtained from the first practical application of the three-component tensometer, designed to determine the entire tensor of deformations upon the surface of a given body(1).

Two investigations were first carried out. Their respective objects were the determination of the Poisson's modulus, and the determination of the

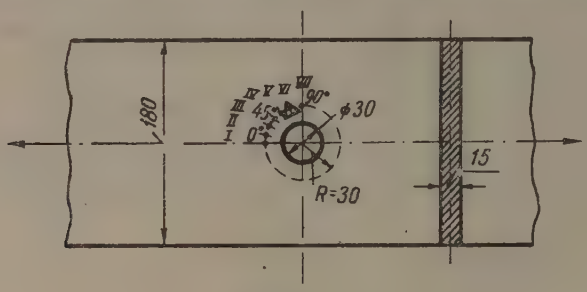


Fig. 1.

concentration of the stresses around the holes. The solutions for both these problems were known beforehand, and therefore we were able to check the operation of the proposed instrument and to state the degree of its precision.

1. Determination of the Poisson's Modulus for Steel 3. A steel test-piece 8 mm long and 3 mm wide was put under tension. The tensometer was fixed in such a way that the tip of leg $\bar{1}$ rested upon the center line of the test-piece, while the basis 23 was perpendicular to the center line. The value of the Poisson's modulus has been determined experimentally as the ratio $\nu = e_{yy} : e_{xx}$ (axis $Ox$ coincided with the center line of the test-piece, while axis $Oy$ was perpendicular to this line; point $O$ is the center of gravity of the triangle 123).

The value for $\nu$ obtained by means of the tensometer was equal to 0.29, agreeing exactly with figures reported in literature.

2. Determination of Distribution of Stresses in a Strip with a Hole under Tension. A test-

piece having a cross-section of 180×15 mm and provided with a hole 30 mm in diameter was put under tension by means of the Werder testing machine. The proposed tensometer was used for the determination of stresses, which was carried out in points of a circumference 60 mm in diameter, concentric with the hole. Seven points have been taken, at 15 degrees intervals, beginning from the diameter coinciding with the center line of the test-piece (Fig. 1).

The tensile load amounted to 10.2 tons (that is $\sigma_0$=377 kg/cm²). The tensometer recorded 1/150 000 of a mm. Elongations $e_{12}$, $e_{23}$, $e_{13}$ were determined by means of the tensometer, and from these data the relative elongations $e_{rr}$, $e_{\theta\theta}$, $e_{r\theta}$ as well as stresses $\sigma_r$, $\sigma_\theta$, $\sigma_{r\theta}$ were calculated [see formulae (1) and (2) of the above-mentioned article]; axes $Ox$ and $Oy$ in each point $O$ were running one along the radius and the other perpendicular to the latter.

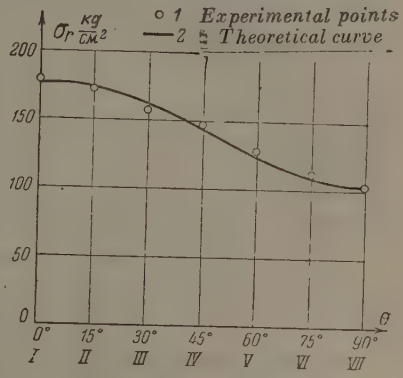


Fig. 2.

The results of the complete experimental determination of the whole picture of stressed conditions ($\sigma_r$, $\sigma_\theta$, $\sigma_{r\theta}$), in points *I*, *II*,... *VII* by means of a three-component tensometer are shown in Figs. 2, 3, 4. The theoretical values for $\sigma_r$, $\sigma_\theta$, $\sigma_{r\theta}$ were computed according to Kirsch' formulae (assuming the strip indefinitely wide).

The above results in the determination of stresses by means of the proposed tensometer confirm the sufficient accuracy of this instrument.

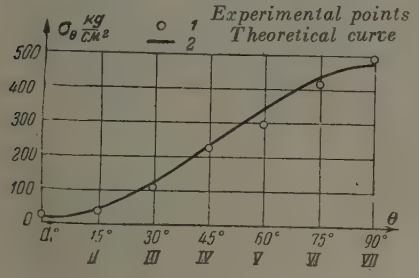


Fig. 3.

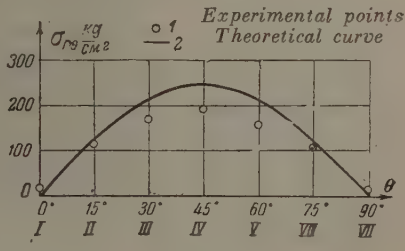


Fig. 4.

The conclusion to be drawn from these first results of practical application of the proposed tensometer to the solution of certain problems of the theory of elasticity is that some questions concerning the strength of materials may be solved expetimentally by its means.

The determination of stresses in various elements of machines and structures by means of the tensometer in question is now in progress and the results will be published soon.

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Chair of Mechanics.

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*PHYSICS*

# ON THE ENERGY LOSSES OF FAST ELECTRONS

By A. I. ALICHANOV, Corresponding Member of the Academy, and
A. I. ALICHANIAN

Of late, the passage of fast electrons through matter has been investigated by several authors; most of them used Wilson's cloud chamber and examined the behaviour of the electrons either in the gas which filled the chamber, or in different absorbing laminae placed in the path of the electrons inside the chamber.

In one of the earliest researches on the subject by Skobeltzyn and Stepanova([1]), abnormally high losses in energy were observed in nitrogen. This circumstance in the case of electrons with an energy of 1—2 MeV led to an almost complete loss of the kinetic energy of the electron. Similar effects have been reported for argon by Leprince-Ringuet ([3]) and by Stepanova ([2]). In the experiments of Ruhlig and Crane ([4]) the electrons passed through a lead block placed across the cloud chamber; for electrons with energies ranging from 0.8 to 1 MeV, losses were observed which by far exceeded those predicted by the theory. Similar results have also been obtained by Laslett and Hurst ([5]) for electrons with energies between 1.5—3.5 MeV traversing thin laminae of lead or carbon.

It must be noted that in the experiments of Ruhlig and Crane, as well as those of Laslett and Hurst, the anomalous values of the average energy loss are due, on the one hand, to single cases of extremely high losses and, on the other hand, to a great number of comparatively low losses. These deviations from the theoretical value of the losses due to ionization and radiation have not yet received a satisfactory explanation.

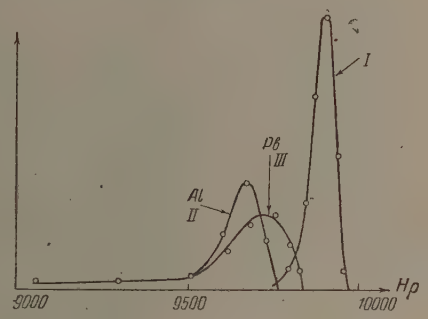
As in our previous investigations, in the present research the method used for determining the energy losses consisted in focusing the electrons in a uniform magnetic field. The source of electrons was an aluminium strip, 0.5 mm wide, coated with an active thorium deposit. In addition to the continuous β-ray spectrum of Th (B+C+C″), a linear spectrum of electrons due to the internal conversion of the γ-rays on the atom shell is emitted by the above source. The internal conversion electrons on the K-shell due to the hardest and most intense γ-line ($h\nu = 2.62 \times 10^6$ eV) possess an energy of $2.5 \times 10^6$ eV which considerably exceeds the maximum energy of the hardest β-spectrum of the active deposit (for ThC, $E_{max} = 2.2 \times 10^6$ eV).

With a spectrograph of sufficiently high resolving power, when the dispersion of the electron beam is only 11°, the internal conversion electrons of the γ-line $2.62 \times 10^6$ eV were obtained in the form of a narrow spectral line. Owing to the narrowness of the source, conversion electrons could be observ-

ed not only from the K-shell of the ThD atom, but also from the L- and M-shells(6).

The above spectral line served for all further determinations of the energy losses of the electrons due to internal conversion of the K-shell of the atom. Different absorbing laminae were placed in front of the electron source, and the variation in the shape of the spectral line was observed resulting from the passage of the electron through the given absorber. The measurements were restricted to an energy interval from 2.55 to $2.2\times10^6$ eV, which is a serious drawback in the method used.

The figure shows typical curves obtained without any absorber and with absorbing laminae of aluminium or lead. Curve *I* represents the original spectral line, curves *II* and *III* refer to absorbers of aluminium (45 mg/cm² thick) and of lead (55 mg/cm² thick) respectively. After having determined the center of gravity of the curves, the average impulse loss $\Delta H\rho$ of the electron can be calculated, and further, the average loss $-\frac{dE}{dx}$.




In the case of both aluminium and lead absorbers, the curves showing the momentum distribution have an extending «tail» towards lower energies, owing to the considerable energy losses occurring in this region. In calculating the average loss it should also be taken into consideration that part of the electrons in this region of the curve may be due to Compton electrons extracted by the γ-line. It is quite easy to compute the maximum value of $H\rho$ at which the Compton electrons begin to play an appreciable part in the phenomenon. The value of $H\rho$ worked out to 9350 has been checked by a special experiment which proved the presence of Compton electrons in the tail of the distribution curve. To this end, a thick aluminium plate (~1 mm) was placed in front of the electron source, and the measurements were made in the usual way. It was found that, from $H\rho=9350$ downwards, the shape of the spectral line is often distorted by the Compton electrons.

The table gives the average losses in lead and in aluminium for different thicknesses of the absorber (allowance being made for the distortion produced by the Compton electrons). The table further contains the specific losses as given by the Bloch formula. In the case of lead, the specific losses consist of those due to ionization and to radiation, the radiative losses, for energies of $2.5\times10^6$ eV, constituting about 10% of those due to ionization processes.

| Absorber | Thickness mg/cm² | $-\frac{\Delta E}{\Delta x}$ ekV /mg/cm² | $-\frac{\Delta E}{\Delta x}$ theor. |
|---|---|---|---|
| Lead | 55.5 | 1.17 | 1.15 |
| » | 23.0 | 1.17 | 1.15 |
| » | 14.0 | 0.95 | 1.15 |
| Aluminium | 45 | 1.58 | 1.50 |
| » | 24 | 1.62 | 1.50 |

The experimental figures for the average energy loss are seen to be in fairly good agreement with those given by the Bloch formula. In conformity with the theory, when traversing a substance with a low atomic number, the electrons experience greater energy losses than when passing through a heavy substance. Our results are in striking contradiction to those recorded by Laslett and Hurst or by Ruhlig and Crane, who obtained much higher values for the average energy loss ($\sim$3 ekV/mg/cm$^2$).

It must be noted that the results obtained by the above authors include particular cases when the electrons emerge from the absorber after having almost lost their initial kinetic energy; though such cases are few, they can noticeably alter the average energy loss. In our experiments these cases obviously do not come into account. However, the discrepancy between our results and those reported by the American authors cannot entirely be put down to these specific losses. Indeed, from the histograms given by Ruhlig and Crane it follows that the number of electrons, which upon traversing a lead lamina 43 mg/cm$^2$ thick lose more than 250 ekV, constitute about 30% of the total number of electrons. On the basis of our curves (Fig. 1), the number of electrons for which the energy loss, in a similar thickness of lead, is equal to 250 ekV and more, would constitute not more than 7 to 10% of the total number of electrons. This follows from the comparison of the surface areas of the spectral curves obtained with and without lead absorbers.

A direct comparison with the data reported by Laslett and Hurst is not so easy, since these authors used somewhat thicker absorbers (158 mg/cm$^2$).

In conclusion, it must be said that the results of our experiments do not allow of any conclusions concerning the cases when the losses in energy experienced by the electrons are very high; the data for normal losses, however, are seen to be within experimental error in agreement with those given by the Bloch formula.

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*PHYSICS*

# ACTION OF GAS EXPLOSION ON SOLID EXPLOSIVES

By K. K. ANDREEV and V. P. MASLOV

*(Communicated by N. N. Semenov, Member of the Academy, 28. VI. 1939)*

According to the hypothesis developed by one of the authors in co-operation with J. B. Chariton([1]), it is necessary that a certain localization, both in space and time, of the initial chain-reaction centers of detonation be established for the detonation to take place. In these circumstances, because of the interaction of neighbouring chains forming the group of centers, the probability of the continuation of the chain becomes unity, finite chains become infinite and the reaction becomes self-propagating*.

Obviously, the condition that the probability of detonation being established will be unity when any agent acts upon the surface of an explosive substance, requires that the surface density of the centers of localization created be greater than a certain critical value.

According to this hypothesis the action of particles with comparatively high energies, sufficient to initiate chains, will not cause an explosion, if their concentration is low. A case, such as the above, may occur when the explosion of a gas acts upon a solid or liquid explosive.

Let us consider as an example the relations existing when a hydrogen-oxygen mixture is exploded in contact with a solid or liquid explosive, such as nitroglycerine. The energy per mole of reaction products liberated by the explosion of a stoichiometric mixture of hydrogen and oxygen is much greater than that liberated e. g. by pyroxyline No. 2. Consequently, the possibility that activation of a molecule of nitroglycerine will take place under the action of an explosion of a hydrogen-oxygen mixture (calculated for one particle of the explosion products) is much higher than if an explosion of

* The above conception was formulated on the supposition that single, infinite chains could not exist in the explosives. However, it was presumed that finite chains, not too short in length, existed. On the above ground, an estimate of the minimum number of centers required to give the localization necessary for detonation was made ([1], page 800). It seems possible, however, to admit that infinitely propagating localizations can occur even if only short or no chains at all exist in the explosives. In fact the decomposition of one molecule of an explosive creates several particles of reaction products having large energies (20—30 Cal.) which are, however, at least as far as secondary explosives are concerned, much smaller than the energy of activation required. When a single molecule decomposes, there is but a small probability for the neighbouring molecule to collide with the 2 or 3 particles produced in reaction and having their total energy sufficient for activation. Contrary to this when localization is established, neighbouring molecules are attacked by several product particles whose total energy is well above the activation energy required and which create infinite chains characteristic of detonation and absent in other forms of decomposition.

pyroxyline No. 2, which, it is well known, causes nitroglycerine to explode even at low densities, takes place.

Since the law of distribution of energy among reaction products in unknown, the energy itself being to a considerable extent due to the directed motion of the particles, we shall assume for the purpose of estimating the order of difference between the two cases (the explosion of a hydrogen-oxygen mixture and that of pyroxyline No. 2 ) that the energy is distributed according to the Maxwell-Boltzmann law. Then, if we take the value of the activation energy of nitroglycerine to be 50 000 cal., the probability of activation by an explosion of hydrogen-oxygen mixture (explosion temperature with initial pressure of 15 atm. =4020°K) will be $1^{-\frac{50\,000}{R\cdot 4020}} : 1^{-\frac{50\,000}{R\cdot 2830}} \approx 14$ times greater than the probability of activation by an explosion of pyroxyline No. 2 (explosion temperature 2830°K)*.

It is difficult, in view of the lack of information regarding the micromechanism of the detonation wave, to calculate the absolute number of molecules impinging on the surface of the nitroglycerine and able to cause the activation of its molecules. However, it will be hardly erroneous to admit that the order of magnitude of the ratio of impinging molecules due to the explosion of a solid body and a gas will be proportional to the ratio of the densities of the explosive and the gas, i. e. in the case of a solid explosive will be $0.2—1.0\times10^3$ times greater than in the case of a gas explosion. If we consider both factors—the greater probability of activation in the case of a hydrogen-oxygen explosion and the smaller density of the gas, then the total probability of activation of unit surface of the explosive will be 15 to 70 times less for a gaseous explosion than for the explosion of a solid. In view of this it is quite probable that an explosion of a gas will not be sufficient to cause the detonation of a solid explosive. On the other hand, the same considerations show that increasing the density of the gaseous mixture one will meet with a critical density (pressure), above which the gaseous explosion will detonate a solid explosive. The above calculation shows that in the case of a hydrogen-oxygen mixture the detonating ability should manifest itself at an initial pressure of the order of 15 atmospheres.

Two series of experiments were made, one with atmospheric and lower pressures, the other with higher pressures.

In the first series of experiments a glass tube 25 mm in diameter and about 1.5 m long was filled with a hydrogen-oxygen mixture after evacuation by an oil pump. A charge of lead azide weighing 15—20 mg was introduced into a branching tube. The fusing of a fine wire in contact with the azide caused the latter to explode, thus detonating the hydrogen-oxygen mixture. About 1 m away from the azide a small amount of explosive in the form of a solidified drop or a large crystal was placed on a piece of iron in the center of the tube. The explosion was photographed. The results of the explosion were also estimated by examining the strip to which the explosive was attached. Picric acid, tetryl and pentaerythrite-tetranitrate were tested. None of these explosives either exploded or burned up when the gaseous mixture had an initial pressure of one atmosphere**. No explosion occurred either when the tetryl and pentaerythrite-tetranitrate were heated up to 100° C, this factor being known to increase the sensitivity of explosives considerably. Experiments using lead azide as the «passive» explosive all gave explosions for initial gas pressures of 760, 400 and 210 mm.

* In both cases the thermal capacities used in the calculation are those given by Lewis and Elbe (2).

** Negative results were obtained also using a somewhat different method with liquid and solid (stable, finely crystallized) nitroglycerine.

In the second series of experiments the gaseous mixture produced electrolytically or obtained by mixing hydrogen and oxygen (64% $H_2$, 33.5% $O_2$, 2.5% other gases) was introduced into a steel tube, 38 mm bore and 1 m long, evacuated before filling to a pressure of 10 mm. As in the first series, the explosion of the gaseous mixture was caused by the explosion of a crystal of lead azide. The passive charge weighing 0.35 g was placed in a small iron or copper tube ($d=7$ mm, $S=0.45$ mm) fixed at a distance of 90 cm from the point where the gas explosion was initiated. The tube holding the charge was filled in its lower part with plaster of paris or lute and made up to the edge with the passive charge. Experiments were made with blasting gelatine, pentaerythrite-tetranitrate and picric acid. Experiment at atmospheric pressures showed that the blasting gelatine does not burn or explode. At higher pressures (5 and 10 atm.) the gelatine burns without deforming the tube. At still higher initial pressures, the blasting gelatine explodes and the upper part of the tube containing the explosive is blown to pieces. To prove that the tube had burst because of the explosion produced by the gas and not because the high pressure and temperature had made the explosive burn, experiments were made with nitroglycerine powder (two experiments: with 0. 35 and 0.7 g at a pressure of 20 atm.) instead of the gelatine. Although a larger charge and a higher pressure were used, no deformation of the tube occurred in these experiments.

Experiments with cast pentaerythrite-tetranitrate showed that neither burning nor explosion occurred at pressures of 6 and 10 atm. At a pressure of 15 atm. the explosive is ignited and at 20 atm. it explodes. Powdered pentaerythrite-tetranitrate ($\Lambda=1$) exploded at initial pressures of 10 and 15 atm. At a pressure of 20 and 24 atm. picric acid burns and at 30 atm. it explodes.

The result of the experiments with secondary explosives is to bear out the deduction made from the above calculations, as well as the hypothesis upon which they were based*. The behaviour of lead azide does not oppose the hypothesis either. Because of the small value of the activation energy of the azide, the number of initial chain centers on its surface will be high, and at the same time, as has been established previously[3], it is possible to assume that in the lead azide as well, as in other initiating explosives, the reaction chains are of much greater length than in secondary explosives. In view of this, it is obvious that interaction between chains in this case will be possible with a concentration of the initial centers on the surface much less than is needed for secondary explosives.

It is not excluded, however, that under the conditions investigated for lead azide the development of the reaction chains brings about a corresponding increase in temperature, thus producing initiation of detonation thermally.

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* Of course it is possible to admit that in our experiments the action of the gaseous explosion is to cause a rapid and intensive heating of the explosive, thus making it detonate. However, if we wish to make this admission with regard to secondary explosives, it will be difficult to explain the fact that in experiments, in which intense ignition of high percentage dynamites and of picric acid took place in closed iron tubes, no detonation occurred.

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*CHEMISTRY*

# CORROSION RESISTANCE OF STEELS WITH VARYING GRAIN SIZE

By B. A. KRASSIUK and I. L. LIPLAVK

*(Communicated by Wl. A. Kistiakowsky, Member of the Academy, 30. VII. 1939)*

The corrosion resistance of metals depends primarily on the nature of the metal and the properties of the protective film coating its surface (1). There are good reasons to believe that the extent to which the protective film is continuous and solid cannot possibly be independent of the properties and the structure of the underlying metal.

It often happens that test samples of steels having the same chemical composition will, in their practical application, display a considerable difference in their properties, although they had previously been subjected to any mechanical or thermal treatment. Numerous investigations (2) have shown the grain size to be of paramount importance here.

In its turn, grain size depends on a variety of factors; thus, metallurgists have all along been aware that heats made in an acid furnace give grain size altogether different from heats produced in a basic furnace; specialists in heat treatment similarly know that the annealing of steels at different temperatures and with different times of holding likewise involves different grain growth in a metal.

The present investigation on the corrosion resistance of steels with varying grain size bears therefore directly upon the problem of the quality of steels and steel products. A new link is added with it to the chain of experiments which have for object to establish the relation between the film properties and the structure of the underlying metal.

Our test samples were specimens of medium carbon steels with a content of carbon varying from 0.40 to 0.45% and with different small additions of alloying elements apt to exert an active influence upon grain growth in course of heat treatment. The chemical composition of the test pieces is given in the annexed table.

The test pieces made from these steels were being annealed in an electric furnace at temperatures varying from 850 to 1200°C, during 3 hours, and a more or less intensive grain growth was in that way obtained in the metal. The grain growth proceeded unevenly in all cases and the differences in grain size after annealing at high temperatures were quite appreciable; it appeared therefore impossible to characterize the steel with enlarged grains by its «mean grain size», and it became necessary to speak of the results in terms of two mean values, one for the small and the other for the large grains. The quantitative relation between the small and the large grains was established by counting the grains under the microscope.

| No. of specimen | C, % | Mn, % | Si, % | P, % | S, % | Additions | $t°$ of tapping, °C |
|---|---|---|---|---|---|---|---|
| 1 | 0.40 | 0.50 | 0.33 | 0.028 | 0.011 | No additions; $Al_2O_3$=0.017% | 1572 |
| 2 | 0.43 | 0.62 | 0.36 | 0.031 | 0.025 | $Al_2O_3$=0.022%, addition to ladle 0.050% Al | 1575 |
| 3 | 0.44 | 0.56 | 0.29 | 0.033 | 0.015 | $Al_2O_3$=0.030%, addition to ladle 0.1% Al | 1535 |
| 4 | 0.45 | 0.68 | 0.32 | 0.030 | 0.018 | $Al_2O_3$=0.033%, addition to ladle 0.2% Al | 1530 |
| 5 | 0.45 | 0.68 | 0.34 | 0.017 | 0.011 | Addition 0.1 % Ti | 1530 |

The tests for resistance to corrosion were preceded by metallographic investigations. After taking photomicrographs of the etched section, the specimens were polished anew and photographed again in a non-etched state. This was done with the purpose to ascertain the amount of non-metallic inclusions and other contaminations which might influence the formation of corrosion centers. In order to be sure that on repeated microscopic examinations the same area of the metallic surface comes into the field of vision, two small incisions at a certain angle were made on the surface of the slice with a razor blade. These served to find the area in question, while repeatedly taking photomicrographs.

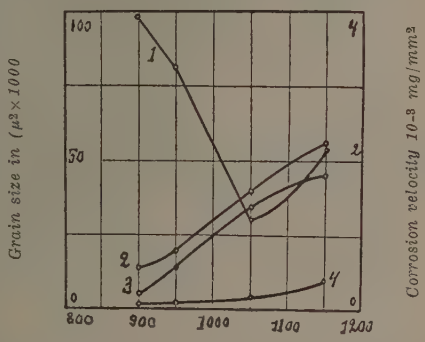


Fig. 1. *1*—Corrosion velocity, *2*—large grain size, *3*—% of large grains, *4*—small grain size.

Having tested various procedures we at last decided upon the method of injecting the metal surface with iodine. This method was suggested by Wl. A. Kistiakowsky ([6]) in 1914 and was later applied by him([7]) and his followers Krotov and Gurovich ([8]) to experimental work. Iodine was used as 0.001 *n* solution in benzene. The surface of the slice after being cleaned and degreased was subjected to the action of the above-mentioned solution during 1 min., and then the sample was carefully washed in alcohol, dried and 3 min. later photographed under a 200× power of the microscope.

Repeated investigaton of the specimens gave almost similar results, which testifies to the fact that the character and the amount of the corrosion centers apt to arise through the action of iodine depend on the main upon the structure of the steel.

The second method of investigation was the ordinary gravimetric method with dissolution in 18% $H_2SO_4$.

The graph shown in Fig. 1 is characteristic of all the kinds of steel used. Here the corrosion resistance of a steel is made evident through data obtained after the method of determining the weight lost on solution in 18% $H_2SO_4$.

Fig. 2 shows the normal typical microstructure of the specimens investi-

gated to be in striking contrast with the surface of the same steels treated with iodine and covered with corrosion centers.

Conclusions. 1) Until a certain limit is reached, grain growth in steel always involves an increase in corrosion resistance. 2) Steel with particularly coarse-grained structure has its corrosion resistance reduced owing to the fact that great amounts of ferrite grow through the pearlite, contributing thus to the formaton of a large number of corrosion centers.

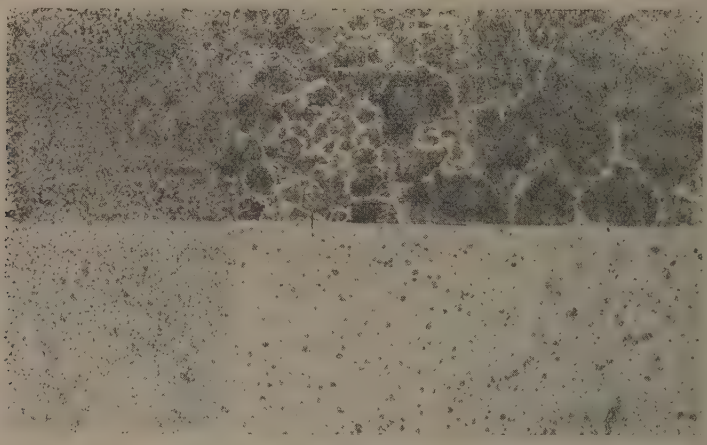

Fig. 2.

3) The method suggested by Wl. A. Kistiakowsky and elaborated by E. I. Gurovich, based on the application of iodine, gives results which agree well with the data obtained by the gravimetric method.

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*PHYSICAL CHEMISTRY*

# ON THE THEORY OF LIESEGANG'S RINGS

By F. M. SHEMIAKIN and P. F. MIKHALEV

*(Communicated by Wl. A. Kistiakowsky, Member of the Academy, 4. VIII. 1939)*

Our experiments (1), begun in 1928, showed, in full accord with Leduc's experiments, that Liesegang's rings are beyond doubt a wave process (standing waves). Hedge's experiments (2) showed that periodic layers form when the sol of the reaction product is coagulated by the diffusing solution of the outer component.

Besides this, periodic layers can be produced as a result of a number of other physical-chemical processes: chemotaxis, corrosion, crystallization, coagulation, etc. Experiments by a number of authors [(3—5) and others] showed that during chemical reactions, particularly during the coagulation of sols and the corrosion of metals, electromagnetic oscillations of a wave length of 1900 to 2500 Å are emitted.

All this makes us assume that during periodic reactions there arise special standing waves of an electromagnetic nature. Then the distance between the layers equals one semiwave and the frequency of these waves (in vacuum) is:

$$\nu = \frac{c}{\lambda} = \frac{3 \cdot 10^{10}}{\frac{2\lambda}{2}}.$$

Calculation for Liesegang's rings give numbers which correspond to the section of the spectrum between Hertz's waves and infra-red waves. Such frequencies could have been called forth by rotational oscillations or by singular luminescence. They may be caused, for instance, by blows of ultra-violet photons or other factors. The formation of standing electromagnetic waves may be: 1) either a secondary effect during the emission of ultra-violet rays or 2) a part of the spectrum which accompanies chemical processes, and whose other part are Oduber's ultra-violet waves. For instance, if we assume that in Liesegang's rings we have a special kind of Raman effect, and that Oduber's and Liesegang's frequencies are satellites, we get:

$$\nu_{sat} = \nu_{bas} \pm \Delta\nu; \qquad \nu_{Odub} = 1.5 \cdot 10^{15}; \qquad \nu_{Lies} = 10^{11}.$$

Hence we get:

$$\Delta\nu \approx 8 \cdot 10^{14}, \qquad \nu_{bas} \approx 8 \cdot 10^{14},$$

i. e. frequencies corresponding to the heat motion of the molecules. The standing waves, probably, form when they are reflected from the border of the

diffusion field which is similar, e. g., to the reflection of radio-waves in Heaviside layer. It should be emphasized that during diffusion which is accompanied by chemical reaction the borderline between the diffusion field and the gel as yet untouched by the diffusion field is very clear, and not washed away as is the case in simple diffusion. All this makes it possible to explain the physical sense of the wave-emission theory of periodic reactions. J. J. Thomson ([6]) showed that under definite conditions electromagnetic waves obey the same laws as material waves without any descriptive physical sense. Hence it is clear that in order to explain periodic reactions there is no need of applying the purely formal conception of material waves, as Christiansen did. It should be added that Maxwell's and Dirac's equations are expressed analogously ([7]).

R. Führt ([8]) established a formal analogy between the generalized diffusion equation and the generalized wave equation. The stationary solutions of these equations are standing waves. The equations take the form of the usual optical equations (of electromagnetic oscillations). Thus, the function $\zeta$ is obtained through usual harmonic standing waves, with a frequency of $\nu = c/\lambda$. Führt gives the following proportion:

$$\Delta x \Delta v = \frac{h}{4\pi m} = \frac{hN}{4\pi M}.$$

Calculations by this formula give numbers which coincide with the optimal periodicity constant values found by experiment.

Table 1

| $\frac{hH}{4\pi M}$ | $1.8 \cdot 10^{-6}$ | $18 \cdot 10^{-6}$ | $1.2 \cdot 10^{-6}$ | $0.8 \cdot 10^{-6}$ |
|---|---|---|---|---|
| Experiments * | $2.2 \cdot 10^{-6}$ | $20 \cdot 10^{-6}$ | $1 \cdot 10^{-6}$ | $1 \cdot 10^{-6}$ |
| Formula | $AgNO_3$ | $NH_3$ | $Na_4P_2O_7$ | $Pb(NO_3)_2$ |
| Molecular weight | 170 | 17 | 266 | 331 |

The frequencies for the Liesegang rings were calculated according to Tower's ([9]) and Morse and Pierce's ([10]) experiments. The results obtained are compared in Table 2. From them we calculated according to the formula of rotational oscillations

$$\nu = \frac{hN}{4\pi^2 M_1 r^2}$$

the distance between the ions of the outer component, which coincided with the data obtained after other methods.

Thus, the numerical values obtained confirm our deliberations. It must be added yet, that the deposit is situated in the loops of the electric oscillations, while the nodes correspond to the intervals between the layers.

C. V. Raman and K. Subbaramiah ([11]) showed not long ago that Liesegang's rings give the phenomenon of interference just like ordinary light waves.

* F. M. Shemiakin, Dissertation.

Table 2

Formation of MnS (Tower)

| | $\nu$ | $\lambda/2$, cm | $\nu_{n+1}-\nu_n$ | Diameter, cm |
|---|---|---|---|---|
| Outer component $MnCl_2$<br>Inner component $(NH_4)_2S$<br>Medium $SiO_2$ | from $5.2 \cdot 10^{10}$ to $0.3 \cdot 10^{10}$ | from 0.29 to 1.25 | average $5 \cdot 10^{10}$ | $d=5.1 \cdot 10^{-8}= 2\sqrt{\frac{hN}{4\pi^2 M_1 \nu_\Delta}}$ |

$$M_1=\frac{m_{Mn} \cdot 2m_{Cl}}{m_{Mn}+2m_{Cl}}, \quad \nu_\Delta = \nu_{n+1}-\nu_n$$

Formation of $Ag_2Cr_2O_7$ (Morse and Pierce)

| | $\nu$ | $\lambda/2$, cm | $\nu_{n+1}-\nu_n$ | Diameter, cm |
|---|---|---|---|---|
| Outer component $AgNO_3$<br>Inner component $K_2CrO_4$<br>Medium gelatine | from $4.4 \cdot 10^{11}$ to $2.1 \cdot 10^{11}$ | from 0.038 to 0.072 | average $3.4 \cdot 10^{10}$ | $d=1.4 \cdot 10^{-8}= 2\sqrt{\frac{hN}{4\pi^2 M_1 \nu_\Delta}}$ |

$$M_1=\frac{m_{Ag} \cdot m_{NO_3}}{m_{Ag}+m_{NO_3}}, \quad \nu_\Delta = \nu_{n+1}-\nu_n$$

Conclusions. 1) It has been shown that Liesegang's rings may be considered as a result of the formation of standing electromagnetic waves. 2) This makes it possible to explain the physical sense of the analogy established by R. Führt and the physical sense of the wave-emission theory of Liesegang's rings. 3) Numerical calculations give values which coincide with experimental data.

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*GEOCHEMISTRY*

# ON GEOCHEMISTRY AND MINERALOGY OF THE CRIMEA

By A. E. FERSMAN, Member of the Academy

1. In June 1939 I took the opportunity of examining a number of mineral deposits* in the Crimea to complete by some few remarks the data summarized by S. P. Popov (1) and P. A. Dvoichenko (2) in their surveys of the matter. The object of my work was to establish the sequence of geochemical processes in the two most interesting petrographical types of the Crimea—the eruptive rocks and the crystalline Upper Jurassic limestones. The question is of importance not only with regard to the Crimea, but it bears upon similar rock types of the Caucasus as well.

2. Geochemically the rocks in the Crimea fall into the following five types at stages:

| | Geophases |
|---|---|
| 1. Magmatic | *A—B* |
| 2. Pneumatolytic | *D—E—F* |
| 3. Hydrothermal | *D—E—F* |
| 4. Katagenetic | *G—H* |
| 5. Hypergene | *(I), K* |

The highest interest in general belongs to the types II and III, whose rôle however in the majority of the Crimean laccoliths is far from being important, and the absence of hydrothermal and pneumatolytic processes is striking in them. Accordingly, the typical ore processes are of little importance too (traces at the Ayu-dag, Limeny, Kara-dag, Eski-orda) and so are also the contact processes (Ayu-dag and oth.).

3. Of special interest are the enclaves which have not been elucidated sufficiently up to the present. An excellent material in this respect is provided by the large quartz diorite quarry in Partenite (3) where enclaves up to 5×8 cm in size are encountered, especially in the northern stope. These appear to be a marly rock, which brought into being a number of minerals and is responsible for the formation of miarols lined with crystals of various compounds:

| | Geophases |
|---|---|
| Quartz | *H* |
| Actinolite (little) | *H* |
| Prehnite | *H* |
| Chalcopyrite (little) | *I* |
| Epidote (very light) | *I* |
| Barite | *K* |
| Calcite | *K—L* |

* The investigation involved the eruptives of Uchan-su, Gaspra, Limeny, Ayu-dag, Partenite, Kuklik, Eski-orda, Kurtsy; the deposits in the sedimentary rocks of Gaspra, Kockluz (Kokkozy), Uzundzha, Baty-Liman.

The general type resembles the crystallization of Alpine veins; analogous veinlets and miarols are known in the porphyrite of the Bulgakov quarry in Kokkozy (4) and in the main quarry in Kurtsy (5).

The succession of crystallization goes along with a decrease in the VEK's of the respective cations and complex anions:

| Mg(Fe) | Ca | Ba | $[SiO_4]$ | $[SO_4]$ | $[CO_3]$ |
|---|---|---|---|---|---|
| 1.05 | 0.87 | 0.67 | 0.70 | 0.70 | 0.40 |

The most interesting and well developed minerals are as follows: epidote, prehnite and rock-crystal.

It is possible to collect very nice hand-specimens from this quarry which is being worked at present.

4. Ore-Veins of Eski-Orda. The large quarry on the right-hand bank of the Salighir, near Eski-orda, deserves much more attention than has been given to it up to now; this is the only polymetallic vein in the Crimea with abundant mineralization.

The following minerals have been noted here:
pyrite, marcasite, sphalerite, greenockite, galenite, chalcopyrite;
nacrite, palygorskite, delessite, leonhardite, celadonite, prehnite;
calcite, malachite, azurite;
quartz, limonite, epsomite and other sulphates.

Contrary to some indications as to the pinching out of the vein, three thick mineralization zones with intensive propylitization and a secondary migration of sulphides were observed in the summer of 1939; this was shown by the small pyrite and marcasite crystals upon the shreds of palygorskite. A network of pyrite veinlets, partly with chalcopyrite, penetrates this quarry rocks in several places.

No doubt the deposit should be prospected for exploitation purposes; first of all it would be desirable to analyze the sulphide samples for rare and noble metals.

5. Geochemistry of the Decomposition of Eruptives. The processes of hypergene decomposition of the numerous eruptives in the Crimea have been very poorly investigated, though they are of particular interest. Greatest attention should be given to the processes of ancient decomposition during the Lower Cretaceous, when the littoral sandstones, marls and conglomerates were enriched with products of chemical and mechanical disintegration of the eruptives, after the latter had emerged for the first time from the sedimentary series which covered them.

The most interesting and the most wide spread minerals in these formations are celadonite and glauconite. The deposit at Kockluz in the Kokkozy valley (7) is especially interesting in this respect, the more so as it is evidently connected with the tectonic line of a latitudinal direction, along which the eruptives of this region are distributed. Mineralogically and geochemically the mineral is a typical celadonite, partly passing to colloidal masses of «Verona earth». Its connexion with the remains of woody matter in the form of black coal masses is of interest. The change in colour of this very abundant and valuable mineral proceeds in a definite order, when oxidation of the ferrous to the ferric oxide with an intermediate combination of the two oxides (of the berzeliite type) take place: green—dark-green—blue-greenish—yellow-brownish.

The deposit is worth our attention both from the scientific and practical standpoint.

6. Geochemistry of Jurassic Limestones. One of the most wide spread minerals in the Crimea is calcite, but in studying

it one has dealt so far with large crystalline formations only([8]). All rocks and particularly the Upper Jurassic limestones are intersected by different generations of calcite of varying paragenesis. Close examination of these beds in the numerous quarries of Gaspra and the Baidary valley shows the following sequence:

1. Calcite synchronous with limestones. Many carbon compounds; partly typical anthraconite or white calcite. Reducing medium.

2. Calcite veins previous to metamorphism. White pure calcite of complex crystalline forms, partly in veinlets pyrite and marcasite grains, rarely anthraxolite. Reducing medium. In industrial grades the veinlets are faulted, closed up, and there is no danger of their splitting when working the stone.

3. Veinlets of yellowish calcite after metamorphism. Yellow tinges, limonite. Oxidizing environment. Along these veinlets sliding takes place easily and fractures are produced. Oxidizing medium.

4. Recent fractures veins and filling of sink-holes. Yellow stalactites and stalagmites. Contain Fe and Mn. Oxidizing medium.

5. The last are hypergene, stalactitic semicrystalline masses of white carbonates, sediments and coatings after drying of shower streams.

Peculiar are the contact calcite veins (hydrothermal, e. g. at Limeny with marcasite) and altered carbonates of «enclaves» in eruptive rocks.

From what has been said it may be seen that a detailed study of the migration of calcium carbonate in sedimentary rocks would be interesting not only from the standpoint of general geochemistry, but also in view of the industrial value of limestones—marbles which have of late been used widely for decorative purposes (Moscow underground railway).

## Conclusions

Examination of the deposits in West Crimea has supplied a number of new mineral bodies, and shown once more that, thorough as this peninsula is investigated, there are many new data to be expected from its further mineralogic and geochemical investigations.

As a practical conclusion, it is necessary to emphasize that a speedy prospecting is desirable of the Kokkozy deposit of bluish-green protective pigments and a sampling of the sulphides of the quarry at Eski-orda for rare and noble metals. A theoretically interesting point to note is that an obvious relation exists between the series of VEK values and the run of all the principal postmagmatic processes.

To inquire into the geochemical features of the Crimea is a very promising task set before us.

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*GEOCHEMISTRY*

# SOIL EXCHANGE CATIONS AND THEIR GEOCHEMISTRY

By I. D. SEDLETZKY

*(Communicated by A. E. Fersman, Member of the Academy, 27.VIII.1939)*

1. Chemical and colloid-chemical investigations of earth's soils conducted in an extensive and thorough manner have shown that only the following five elements (in order of their increasing occurrence in soils): Ca, Mg, H, Na and K are to be found among the principal exchange cations of the soil absorptive complex. The other metals of the Mendeleyev table, such as Li, Rb, Cs, Zn, Cu, Al, Fe etc., do not occur in an exchange condition at all in the soil absorptive complex, or else, are indeed found there as exchange cations, but in insignificant quantities (1). Even such an element as potassium occurs in soils in the exchange state only in negligibly small amounts.

2. Such a specific condition of Ca, Mg, H, Na and K among the other elements occurring within the earth's surface has not been explained satisfactorily as yet. It might have been believed that calcium, magnesium, hydrogen and sodium occur in soils in larger amounts than, say, potassium. At the same time the Clarke's number of potassium is 10 times that of magnesium ($10^{-1}$) and equals that of sodium ($10^{0}$). The Clarke's number of calcium in soils is about $10^{0}$ (?), whereas that of hydrogen ($10^{1}$), yet exchange calcium is of most frequent occurrence in soils, being found even more often than magnesium, hydrogen, sodium, etc. (5).

The reason why this phenomenon should have remained unexplored, is that there has been no adequate knowledge of the soil absorptive complex forming colloidal soils and clays.

3. Recent inquiry into the mineralogical constitution of soil and clay colloids has shown that the following colloidal minerals (Table 1) are largely present in them (3,2).

Table 1

Principal Soil and Clay Minerals

| Groups of minerals | Names of minerals | Their chemical formula |
|---|---|---|
| Calcium and magnesium minerals | Montmorillonite | $(Ca, Mg)O \cdot Al_2O_3 \cdot 4-5SiO_2 \cdot n H_2O$ |
| | Beidelite | $(MgO) \cdot Al_2O_3 \cdot 3SiO_2 \, nH_2O$ |
| Acid hydrogen minerals | Kaolinite | $(H) \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ |
| | Nacrite | |
| | Dickite | |
| | Halloysite | $(H) \cdot Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$ |
| Sodium and potassium minerals | Gedroitzite | $(Na_2O) \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ |
| | Muscovite (Sericite) | $(K_2O) \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ |

All the minerals entering into the composition of soil colloids are shown in the table to fall into three large groups: 1) magnesium and calcium alumosilicates (montmorillonite and beidelite); 2) acid hydrogen minerals (kaolinite, dickite, nacrite, halloysite, etc.); 3) sodium and potassium minerals (gedroitzite and muscovite or sericite).

It will be apparent that the colloidal minerals occurring in soils include the metals: Ca, Mg, H, Na and K in their composition. And it is just these cations that have been reported forming the principal cations of soils. Accordingly, we may point out the existence of a close connexion between the composition of colloidal soil minerals and soil exchange cations. The fact that this is not a mere coincidence is also evidenced by the connexion existing between the composition of clay minerals and their exchange cations.

The group of bentonite clays having a montmorillonite composition always contains calcium and magnesium as exchange cations, while in kaolin clays the latter are represented mainly by hydrogen. In general, the paragenesis of the soil colloids depends upon the paragenesis of pedolites.

4. The changes in the composition of ground rocks brought about by soil-forming processes are liable to run toward the formation of such secondary minerals which contain Ca, Mg, H, Na and K in preference. The weathering of eruptive materials proceeds, naturally, with the assistance of biological factors. This process involves a variety of rocks laying open on the earth's surface and results in the formation of soils and various loose geological formations (loesses, clays, etc). The main components of these superfacial formations are calcium, magnesium, hydrogen, sodium and potassium alumosilicate secondary minerals ([3]).

The calcium, magnesium, hydrogen and potassium of eruptive rocks will in the process of soil formation become fixed in the lattices of the newly formed argillaceous minerals. Inasmuch as the rest of the cations of eruptive soils fail to take part in building-up newly formed secondary minerals, they become removed from the soils. Hence the character of the migration of elements in soils depends upon definite geochemical conditions, which lead to the formation of argillaceous minerals of a definite composition. It is by the composition of colloidal minerals in soils that the prevalence of the exchange cations of Ca, Mg, H, Na and K can be explained.

This conclusion goes to confirm the importance of lattices energy laws in soil science pointed out by A. Fersman, as well as his claims with regard to the necessity of studying the paragenesis of elements on the basis of the paragenesis of minerals ([2,3]).

5. With respect to soil types, the exchange cations are distributed very irregularly. In black soils they are largely represented by Ca and Mg; in podzol soils hydrogen takes up 80—96% of the exchange volume, and only 20—4% fall to the share of Ca and Mg. In solonetz soils the decisive part is played by Na which comes up to 50—70% of the exchange capacity (30% are taken up by Ca and Mg). Should the exchange cations be connected with the mineralogical composition of the soil absorptive complex, we would have different compositions of pedolites in different types of soil. Such a dependence does actually exist (Table 2).

In the soil absorptive complex of solonetz soils we never come across kaolin minerals, which circumstance stands in perfect agreement with the composition of exchange cations where hydrogen is absent ([2,3]). In podzol soils rich in kaolin minerals hydrogen is predominant among exchange cations. The existence of exchange Ca and Mg in podzol and solonetz soils is accounted for by the presence in the soil absorptive complex of montmorillonite and beidelite which are available in podzol soils as detrite minerals. And, finally,

Table 2

Various Exchange Cations with Reference to Mineralogical Composition of Soil Colloids

| Type of soil | Exchange bases of soil | Composition of colloid minerals | Exchange bases of minerals |
|---|---|---|---|
| Black soil thick layer | Ca, Mg | Montmorillonite | Ca and Mg |
| Solonetz, sodium type | Na | | |
| | Ca | Gedroitzite | Na and K |
| | Mg | Montmorillonite | Ca and Mg |
| | H | Kaolinite | H |
| Podzol | Ca | Montmorillonite | Ca and Mg |
| | Mg | | |

the colloids in black soils consist of montmorillonite, and among the exchange bases more than 90% is taken by Ca and Mg. This fact is strong evidence that there is a dependence between the composition of soil exchange cations and the mineralogical nature of the soil absorptive complex.

6. The close relationship existing between exchange cations and the mineralogical composition of soil colloids points to the peculiar character of the structure of soil minerals. Primary minerals of eruptive rocks, for instance anorthoclase (NaK) $AlSi_3.O_8$, though containing K, Na, Ca, Mg, and other metals, possess, however, cations fully capable of being exchanged, which fact can be explained by the closely packed texture of the minerals in question. Secondary argillaceous minerals of the soil are loose and frequently also highly mobile elastic structures of the montmorillonite type, fit to favour the exchange. That the latter are present in soil colloid minerals emphasizes the specificity of these minerals and the peculiar pattern of their crystalline lattices, admitting of a considerable exchange of cations. Montmorillonite, for instance, is capable of exchanging 100% of its total calcium and 32% of its magnesium, while gedroitzite exchanges 50% of its total sodium.

In connexion with this it is well to note that the amount of exchange potassium in soils is very low, compared to the other four exchange cations: Ca, Mg, H and Na. This can be explained by the fact that potassium enters mainly into the composition of muscovite-sericite which exchanges but 3—5% of its total potassium.

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*GEOCHEMISTRY*

# SPECTROSCOPIC INVESTIGATION OF THE PRODUCTS OF AN ARSENIC PLANT

By S. A. BOROVICK

*(Communicated by A. E. Fersman, Member of the Academy, 20. VIII. 1939)*

Our study of the products obtained from industrial processes at non-ferrous metallurgical plants has yielded a number of valuable results, having shown the presence in these products of rather considerable concentrations of such rare elements as In, Ge and Cd. In the present paper we provide data on the concentration of these elements, as well of tellurium in the products of metallurgical operations at one of the copper-smelting works of the Urals.

Sample No. 1. Average monthly sample of Cottrell dust during March 1938. The dust was obtained after electrostatic cleaning of a mixture of flue gases from the blast furnace and the reverberatory furnace departments.

Sample No. 2. Average monthly sample of the dross from the roasting furnace during March 1938. The dross is a waste product from the roasting of a charge consisting of Cottrell dust, coal dust and dust from Sterling boilers.

Sample No. 3. The sample was taken from a bag filter; the materials were obtained as a result of additional cleaning of gas from the roasting furnace at a temperature of 50 to 60° C. The primary precipitation of arsenic trioxide was effected in a Grum-Grjimailo cascade-type chamber.

Sample No. 4. The treatment of Cottrell dust was modified with a view of extracting its valuable constituents. For this purpose as a first step resort was made to melting the briquets of Cottrell dust in a a round blast furnace, in a reducing atmosphere. Cu, Au, Ag, Fe, Al, Si, Mg, Ca and part of Pb and S passed into the matter, while work-lead went into the slag. The furnace gases were cooled and filtered in a bag filter; it is the product obtained from this filter that constitutes sample No. 4.

Sample No. 5. With a view to extract the metal values the blast furnace received a charge of dross, coke breeze and Cottrell dust. A self-fluxing material was obtained; Cottrell dust was introduced as a binder for briquetting the dross. And it is by melting this product that sample No. 5 was extracted from it.

The spectroscopic method described in our previous papers (²) was applied to work with these samples.

We found the following distribution of elements in them: tellurium is concentrated in all samples with the exception of No. 5; germanium is concentrated in all samples with the exception of No. 1; indium is to be found in small quantities in all samples, the concentration is, however, negligible in

No. 5; cadmium is present in all samples but the concentration is the greatest in No. 4; tin in rather considerable concentrations is found in samples Nos. 3, 4 and 5; in No. 2 an insignificant concentration of molybdenum is available; bismuth is present in small quantities in all samples; the behaviour of antimony is quite different—this metal is concentrated in Nos. 1, 3 and 5; in the rest of the samples its concentration is by far less.

The above-mentioned metallurgical products thus contain germanium, tellurium and cadmium in quantities which have a definite industrial importance. The fact that they contain tin, further contributes to enhance their value. Should it just now be difficult to begin the recovery of germanium and other rare elements from these products, steps should be taken for their preservation so that the valuable metals concentrated in this disposable waste should not become lost.

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*GEOLOGY*

# MONTMORILLONITE FROM WEST SULYUKTA

By S. M. YUSSUPOVA

*(Communicated by L. I. Prassolov, Member of the Academy, 15. VIII. 1939)*

1. The montmorillonite clays find a wide technical application owing to the peculiar properties of this mineral. They exhibit a good plasticity, a high strong swelling and a high sorption capacity. The montmorillonite clays are the best of bleaching clays. The origin of montmorillonite clays has not been definitely established as yet, and therefore, their study is also of high theoretical interest.

2. So far montmorillonite clays have not been detected within the territory of the Middle Asia republics, according to Luchitsky(1). The industrialization of the country, however, urges the search for refractory clays.

3. While collecting material for the investigation of clays and loesses of Middle Asia, attention was paid to the clay from West Sulyukta which swelled very well and was readily forming soap (reminding of the Crimean kill clays). The local population used this clay as an addition for the production of laundry-soap and for the bleaching of wine. This made us carry out a detailed investigation of the clay from West Sulyukta.

4. The Sulyukta brown-coal deposit is located south-eastward of Dragomirovo, a station of the Middle Asia railway, Uzbek SSR.

According to Preobrazhensky (2) this clay is of Jurassic origin; it occurs under a coal-seam. In appearance the clay is of a grey colour, compact, unstratified, oily to the touch. The clay alternates with coal-seams. Charred plants are often encountered. The clay has the following chemical composition (in %):

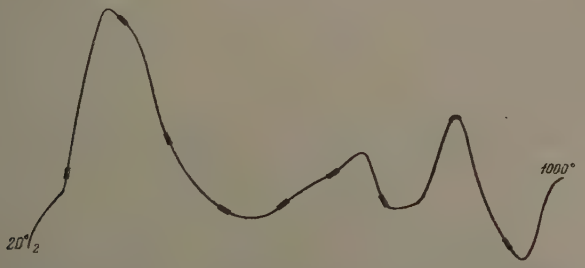
| | | | |
|---|---|---|---|
| $SiO_2$ | 57.3 | $Na_2O$ | 0.31 |
| $Al_2O_3$ | 23.60 | $K_2O$ | 1.72 |
| $Fe_2O_3$ | 1.95 | $H_2O$ | 6.5 |
| $TiO_2$ | 0.21 | Loss on ignition | 6.32 |
| CaO | 1.90 | $SiO_2/Al_2O_3$ | 4 : 1 |
| MgO | 5.18 | | |

The high magnesium content (5.18%) and the ratio $SiO_2/Al_2O_3$ equal to 4 : 1 indicate the montmorillonite composition of the clay.

5. In order to determine the mineralogical constitution of the clay, thermal and X-ray analyses were carried out to which clay itself and its mud fraction were subjected. The thermal analysis according to the differential method of Le-Chatelier was carried out in the laboratory of the Institute of Economic Mineralogy (see diagram curve). As it may be seen from the curve, this clay has the following thermal terraces:

I—160°—endothermal, characteristic of montmorillonite
II—650°—endothermal, characteristic of kaolinite (the shift to the right appears to be due to the inconsiderable calcium content)
III—800°—endothermal, characteristic of montmorillonite
IV—920°—exothermal terrace, characteristic of kaolinite.

Such an interpretation of the curve shows that the Sulyukta clay consists chiefly of montmorillonite and an inconsiderable quantity of kaolinite and calcite.




6. The X-ray data are an excellent proof of the thermal data; the analysis was carried out by the Debye-Sherrer method with a Haading tube; 25 kV, 12 mA, exposition 12 hours. The X-ray data are given in the table.

X-Ray Analysis of the Sulyukta Clay

| Fraction radiogram 0.002 mm | | | Fraction radiogram 0.01—0.001 mm | | | |
|---|---|---|---|---|---|---|
| Intensity | *d (hkl)* | Mont-mor. | *d (hkl)* | Intensity | Mont-mor. | Kaolinite |
| Weak | 7.41 | + | 4.50 | Very strong | + | + |
| Strong | 4.38 | + | 4.05 | » » | — | + |
| Medium | 3.02 | + | 3.63 | Weak | — | + |
| » | 2.54 | + | 3.05 | » | + | + |
| Weak | 1.68 | + | 2.82 | Medium | — | + |
| » | 1.64 | + | 2.53 | Strong | + | + |
| Strong | 1.46 | + | 2.25 | Medium | — | + |
| Medium | 1.27 | + | 1.70 | » | + | + |
| » | 1.24 | + | 1.65 | Strong | + | + |
| | | | 1.50 | Medium | + | + |
| | | | 1.46 | Strong | + | + |
| | | | 1.40 | Weak | — | + |
| | | | 1.28 | Medium | + | + |
| | | | 1.25 | » | + | + |

From the data of the table it may be seen that different clay fractions contain different minerals. While the fractions from 0.01 to 0.001 mm are composed of montmorillonite and kaolinite, the clay colloids contain chiefly montmorillonite. But on the whole the clay certainly consists of montmorillonite and kaolinite, which is shown by the heating curve.

7. Thus, we encounter the coexistence of montmorillonite and kaolinite in clay.

Noll ([3]) has already shown that montmorillonite and kaolinite are formed under different conditions. Later on Sedletzky ([4]) showed in a number of works that montmorillonite and kaolinite could not possibly be formed under simi-

lar conditions. He confirmed his opinion by his materials on grounds and clays. As to the joint occurrence of these two minerals, Sedletzky (5) explains it by the fact that such clays and soils are just now in an intermediate stage, when conditions characteristic of montmorillonite (alkaline medium) are replaced by conditions (acid medium) of kaolinite formation.

On the basis of this hypothesis we may regard the Sulyukta clay a result of the influence of two processes: under the influence of alkaline of weathering montmorillonite clay was the first to form and on its further joint deposition with coals was subjected to the influence of humic acid. As a result of acid weathering kaolinite is formed in montmorillonite clay in inconsiderable quantities. This is confirmed by the presence of quartz in the coarse fraction of clay.

The question as to why montmorillonite is concentrated in a finer fraction of clay while kaolinite is present in its coarser portion, finds its solution in the varying size of crystallites which is a distinctive feature of these two minerals.

8. Among the data of the chemical analysis we see 23.60% $Al_2O_3$, which characterizes favourably this clay, since $Al_2O_3$ is a factor increasing refractivity. It has been supposed that this clay must have a high melting point, and, indeed, this supposition has been confirmed. The fusibility range of this clay is from 1720° to 1780°C. The clays with such a fusibility temperature belong to refractory clays, and therefore the Sulyukta clay may certainly be classed within this sort of clays, too.

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*PHYSIOLOGY*

# SPONTANEOUS SALIVARY SECRETION IN HUMAN TWINS. I

By I. KANAEV

*(Communicated by L. A. Orbeli, Member of the Academy, 16. VII. 1939)*

Spontaneous, basic or «continuous» salivary secretion in human beings has been noted by numerous authors. Biriukov ([1]) devotes to spontaneous secretion a whole chapter of his book, supplying in it a critical review of the literary data and some data of his own. Spontaneous secretion in man has been but little studied, its causes remain obscure. However, in work on the salivary reflexes of children one has always to deal with spontaneous secretion, which is here, in the first place, the «background» against which conditioned stimulation is acting. In my work on the genetics of higher nervous activity in twins, I could not help approaching the study of certain peculiarities of spontaneous secretion. I studied spontaneous secretion in 8 pairs of twins of school age: 5 of these were unioval (UT), i. e. with an identical heredity, 3—bioval (BT), i. e with a different heredity. Every pair had lived in their childhood in, generally speaking, similar conditions, though of course their life history did not develop under similar influences of the medium in all details. The work was begun in 1936 and conducted mainly in the laboratory of Prof. N. I. Krasnogorsky and ended in the Institute for Medical Qualification.

The following method was used: the saliva was obtained from both gl. parotis with the aid of Krasnogorsky's «funnels», and its secretion was recorded on the tape of a cymograph during 30 min. 10 such records were taken for each child. These records supplied precise data on the dynamics of the process of spontaneous salivation and could be considered under various aspects, the statistical included. I present here the data obtained by counting the number of drops for 30-sec. intervals. Every 30 min. record supplied a range of 60 figures. The first two were rejected, the remaining 58 summarized in tables, demonstrating the dynamics of secretion in its natural time course in the first place. Spontaneous secretion varied greatly in the same child on different days and at different moments of the 30-min. interval. Different children were found, however, to be in some cases readily distinguishable in respect of the quantity and variability of their spontaneous secretions. The statistical consideration of the material allows to demonstrate these differences mathematically. For this purpose we counted for every day the number of 30-sec. intervals during which no drop of saliva was secreted, the number of intervals with 1 drop of saliva, with 2 drops etc., and constructed of these numbers a variation range. Such ranges were constructed for each and one general range for all of the 10 test days. The mean value ($\overline{X}$) and the mean

square deviation (σ) were calculated for each range. These values for all the 8 pairs of twins are given in Table 1.

Table 1

Mean Values ($\bar{X}$) and Mean Square Deviations (σ) of Spontaneous Secretions

| No. of exp. | Unioval twins | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | | | | I-za | | | | Kudr-y | | | | Sm-y | | | |
| | Tamara | | Nina | | Vera | | Nadia | | Galia | | Lucy | | Ghena | | Vova | |
| | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ |
| 1 | 4.79 | 2.25 | 1.52 | 1.09 | 1.79 | 1.55 | 1.90 | 1.42 | 1.14 | 0.84 | 1.14 | 1.40 | 3.42 | 1.80 | 4.21 | 1.59 |
| 2 | 6.24 | 2.83 | 1.85 | 0.90 | 1.81 | 1.38 | 3.24 | 1.46 | 1.90 | 1.86 | 1.79 | 2.56 | 1 11 | 0.95 | 4.09 | 2.62 |
| 3 | 6.55 | 4.38 | 1.40 | 1.41 | 1.52 | 1.59 | 2.03 | 1.52 | 1.05 | 1.89 | 1.26 | 1.29 | 0.61 | 0.69 | 2.40 | 2.19 |
| 4 | 4.83 | 4.17 | 2.07 | 1.15 | 2.22 | 2.08 | 2.40 | 1.27 | 2.81 | 1.44 | 1.07 | 1.59 | 0.28 | 0.45 | 1.77 | 1.54 |
| 5 | 5.10 | 4.22 | 1.53 | 1.00 | 1.57 | 1.32 | 1.69 | 1.77 | 1.02 | 0.80 | 1.07 | 1.16 | 1.23 | 1.04 | 1.46 | 1.15 |
| 6 | 3.26 | 2.44 | 1.43 | 1.30 | 1.64 | 1.36 | 1.07 | 1.17 | 1.43 | 1.53 | 1.09 | 1.40 | 0.30 | 0.59 | 1.49 | 1.50 |
| 7 | 7.79 | 6.11 | 1.00 | 0.98 | 2.16 | 1.30 | 1.72 | 1.45 | 0.83 | 1.17 | 0.50 | 0.79 | 0.28 | 0.48 | 0.75 | 0.96 |
| 8 | 3.33 | 4.16 | 1.41 | 1.53 | 1.19 | 1.26 | 1.45 | 1.55 | 2.52 | 1.69 | 2.07 | 1.35 | 1.56 | 1.83 | 0.11 | 0.32 |
| 9 | 5.09 | 4.49 | 2.12 | 1.51 | 1.21 | 0.95 | 2.41 | 1.95 | 2.55 | 2.20 | 0.81 | 0.89 | 1.09 | 1.50 | 0.11 | 0.32 |
| 10 | 2.86 | 3.25 | 1.93 | 2.73 | 1.03 | 1.27 | 1.69 | 1.26 | 2.57 | 1.56 | 0.91 | 0.91 | 0.07 | 0.26 | 0.46 | 0.84 |
| Σ | 4.98 | 4.25 | 1.63 | 1.49 | 1.61 | 1.48 | 1.96 | 1.61 | 1.78 | 1.73 | 1.17 | 1.50 | 0.99 | 1.45 | 1.68 | 2.05 |

Table 1 (continued)

| No. of exp. | Unioval twins | | | | Bioval twins | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kon-y | | | | B-vy | | | | L-vy | | | | M-r | | | |
| | Luda | | Nadia | | Donara | | Rid | | Valia | | Nina | | Ella | | Minna | |
| | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ | $\bar{X}$ | σ |
| 1 | 1.24 | 0.97 | 0.74 | 0.60 | 0.24 | 0.54 | 1.21 | 1.07 | 1.03 | 1.01 | 1.97 | 1.85 | 0.69 | 0.72 | 1.12 | 0.84 |
| 2 | 2.40 | 1.89 | 1.05 | 0.69 | 0.07 | 0.26 | 0.36 | 1.23 | 1.26 | 1.61 | 2.36 | 1.87 | 1.84 | 1.61 | 0.52 | 0.66 |
| 3 | 1.97 | 1.01 | 0.43 | 0.50 | 0.60 | 0.64 | 0.64 | 0.76 | 1.29 | 2.08 | 2.53 | 1.82 | 1.78 | 1.69 | 0.16 | 0.37 |
| 4 | 1.90 | 2.54 | 0.93 | 0.77 | 0.97 | 1.30 | 1.31 | 1.46 | 0.71 | 2.36 | 1.05 | 1.17 | 2.29 | 1.37 | 0.84 | 1.01 |
| 5 | 1.41 | 1.73 | 1.26 | 2.00 | 0.52 | 0.84 | 1.41 | 1.27 | 2.16 | 1.68 | 1.09 | 0.89 | 2.91 | 1.45 | 0.78 | 1.13 |
| 6 | 2.00 | 1.19 | 0.55 | 0.91 | 0.26 | 0.48 | 0.79 | 0.74 | 0.84 | 1.78 | 4.28 | 5.18 | 2.40 | 1.39 | 0.59 | 1.51 |
| 7 | 2.38 | 1.34 | 1.03 | 0.89 | 0.90 | 0.87 | 2.72 | 2.64 | 2.05 | 1.36 | 1.17 | 1.77 | 1.97 | 1.85 | 0.14 | 0.35 |
| 8 | 0.67 | 0.85 | 1.57 | 1.34 | 0.17 | 0.41 | 1.40 | 1.73 | 0.40 | 0.85 | 0.48 | 0.93 | 2.19 | 1.28 | 0.64 | 1.03 |
| 9 | 0.69 | 0.59 | 0.60 | 0.98 | 0.17 | 0.46 | 0.72 | 1.49 | 2.00 | 1.95 | 3.81 | 2.15 | 2.00 | 1.47 | 0.79 | 1.11 |
| 10 | 1.45 | 1.39 | 1.62 | 1.05 | 0.59 | 0.67 | 0.79 | 1.01 | 0.62 | 1.19 | 4.21 | 4.73 | 2.97 | 1.86 | 0.62 | 0.72 |
| Σ | 1.61 | 1.57 | 0.98 | 1.13 | 0.45 | 0.77 | 1.14 | 1.57 | 1.24 | 1.76 | 2.29 | 2.97 | 2.10 | 1.62 | 0.70 | 1.01 |

It is probable that further studies on spontaneous secretion may supply interesting data for the characteristics of the functional properties of the nervous system of individual persons, since even the figures of our table indicate sometimes clean-cut individual differences of spontaneous secretion even in UT, as, for instance, in Tamara and Nina.

The comparison of the differences in the mean values within each pair gives the following data (Table 2).

Table 2

| UT group | | BT group | |
|---|---|---|---|
| In. 3.35 drops<br>Kudr. 0.65 »<br>Kon. 0.63 »<br>Sm. 0.69 »<br>Lab. 0.35 » | Error of diff. — 0.18 drop<br>» » » 0.095 » | Moz. 1.40 drop<br>Lar. 1.05 »<br>Bogd. (boy and girl) 0.69 drop | Error of diff. 0.072 drop |

Judging by the calculated errors of differences, all the figures presented by us seem to possess real significance. We see that the difference within one pair of UT may be even greater than within one pair of BT (e. g. UT pair In., Tamara and Nina). This must be probably interpreted in the sense that spontaneous secretion is determined in a high measure by factors of the surrounding medium, while the hereditary differences in the nervous system are but little reflected by it. It is worth noting that approximately the same considerable difference in spontaneous secretion was established in the UT In. in January 1936, in October 1937 and in the spring of 1938: in Tamara spontaneous secretion is at least twice as high as in Nina. This seems to indicate that certain functional alterations of the nervous system, having arisen under the influence of surrounding factors, may be preserved and become a characteristic feature of the nervous activity of an individual, and that such differences may arise on the base of one genotype, as, e. g., in the UT Nina and Tamara.

The high variability of spontaneous secretion sometimes, as one can see from the sigmas of our table, even within quite short time intervals indicates, probably, that we must consider this secretion as the result of a very intricate interaction of various cortical and subcortical processes, which it will be possible to estimate only after further studies on cerebral physiology.

The correlation between spontaneous secretion as the «bakground», and conditioned and unconditioned secretion has been studied by me on one pair of twins (UT In.).

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*PHYSIOLOGY*

# UNCONDITIONED SALIVARY REFLEXES IN HUMAN TWINS. II

By I. KANAEV

*(Communicated by L. A. Orbeli, Member of the Academy, 16. VII. 1939)*

Unconditioned salivary reflexes in human persons have been studied on numerous occasions according to the methods of Lashley and Krasnogorsky(4) [cf. the review by Biriukov (1)]. Unconditioned reflexes are regarded by the Pavlov school as undoubtedly «innate» reflexes, i. e. as prevalently hereditary.

It seemed interesting to verify this conception and to establish simultaneously in what measure such a reflex may suffer alterations under the influence of environmental factors. For this purpose I studied unconditioned secretion in 4 pairs of unioval twins (UT) and 3 pairs of bioval twins (BT), i. e. applied the twin method used in genetic studies(2).

These twins were children of school age and every pair grew up from its birth under approximately the same conditions of everyday life. The unconditioned secretion was collected with the help of Krasnogorsky's «funnels» from both gl. parotis in the course of experiments on conditioned secretion.

The output of saliva was recorded on the tape of a cymograph with precision to one drop.

Time was recorded on the same tape in seconds, so that it was possible to register the change in unconditioned secretion with time. On the tape we read how many drops had been yielded during the first, second, third etc. 5-sec. interval, for 100 sec. beginning with the moment, at which food was administered (six sugar-coated cranberries) or a definite dose of cranberry-juice which served to strengthen the effect. 20 such 100-sec. periods of unconditioned secretion each on a different test-day were recorded for each child.

After this we calculated the mean 20 values of secretion for the first 5-second interval, for the second interval, etc., the calculations being repeated for each of the children. Similarly we calculated also the mean square deviations (i. e. $\sigma$) for each of the mean values thus obtained.

These deviations characterize the variability of the secretion. The figures thus obtained are summarized in Table 1 (pp. 220—221).

The analysis of Table 1 shows the following:

1. Unconditioned salivation provoked by cranberries increases rapidly in all children beginning with the second 5-sec. interval, but starts decreasing as early as in the next 10 seconds at a varying rate in different children.

Secretion in response to juice increases at a slower rate, holds on all the time juice is supplied and sinks at a slower rate than in the case of cranberries.

2. The process of unconditioned salivation varies sometimes quite considerably, as this may be judged by the σ-values, in connexion with surrounding influences on the nervous system, with the general condition of the organism, etc.

3. The unconditioned secretion of each child shows an evident individual character; this appears with particular clearness when the respective figures are expressed in the shape of variation curves.

4. The individual peculiarities of unconditioned secretion are relatively stable and may be observed again after a lapse of 2—3 years (e. g. in the twins Lar. and B.).

5. It is of particular interest that unconditioned secretion unlike spontaneous secretion shows in unioval twins, i. e. in twins with identical heredity, a greater similarity within each pair, than in bioval twins.

6. However, within one pair of indubitable UT, Vova and Ghena Sm., a quite considerable difference, no less than within one pair of BT, was observed.

7. This difference within the pair can be expressed by one figure of the number of drops, if, e. g., one calculates the difference between the amount of unconditioned secretion of both twins for the first ten 5-second intervals.

With increasing age the difference within the pair sometimes becomes noticeably larger The figures for these differences within each pair are supplied in Table 2.

Table 2

| UT group | BT group |
|---|---|
| Lab. — 3.65 (1935) and. 3.15 (1937) | Moz. — 14.1 |
| Inoz. — 7.0 (1935) » 9.7 (1937) | Lar. — 16.4 |
| Kudr. — 7.1 | Bogd. — 26.1 (1934) and 54.0 (1937) |
| Sm. — 14.0 | |

As one can see, the greatest difference within a pair among the UT coincides with the lowest among the BT. This certainly speaks for the considerable rôle of heredity in the process of unconditioned secretion. And alongside of this the already mentioned relatively great difference within the UT pair Sm. induces one to suppose, that even such an «innate» process, as the unconditioned reflex, may sometimes suffer prolonged and essential alterations under the influence of the surroundings. Since, however, the general life conditions of these children were similar, this difference has resulted from relatively small, may be even hardly noticeable differences in the effects of the surroundings on them in the course of the individual histories of the development of these children.

Table 1

Mean Values ($\bar{X}$) and Mean Square Deviations ($\sigma$) of Unconditioned Secretion, Expressed in Drops for 5-sec. Intervals

I Group UT

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. I. Tamara (1934) | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 7.2 | 11.2 | 9.8 | 7.0 | 5.9 | 5.3 | 5.6 | 4.0 | 5.1 | 5.6 | 4.1 | 3.9 | 3.9 | 3.1 | 3.9 | 3.4 | 3.7 | 3.5 | 3.4 | 2.9 |
| $\sigma$ | 3.0 | 2.1 | 2.4 | 2.1 | 3.4 | 3.2 | 3.0 | 2.5 | 3.2 | 3.8 | 2.9 | 2.5 | 3.1 | 2.4 | 3.2 | 1.9 | 2.4 | 2.6 | 2.6 | 2.5 |
| Nina (1934) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 8.1 | 11.1 | 9.6 | 9.1 | 7.0 | 6.6 | 5.6 | 5.5 | 5.8 | 4.7 | 4.5 | 4.2 | 4.1 | 3.2 | 3.1 | 3.2 | 2.7 | 2.4 | 2.4 | 1.7 |
| $\sigma$ | 3.6 | 3.0 | 2.9 | 2.9 | 2.6 | 3.1 | 3.0 | 3.1 | 2.6 | 3.0 | 3.4 | 3.0 | 3.1 | 2.6 | 2.1 | 2.3 | 1.8 | 1.8 | 1.7 | 1.3 |
| 2. I. Tamara (1935) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 5.1 | 8.9 | 8.2 | 7.7 | 6.5 | 6.5 | 5.3 | 3.7 | 3.2 | 2.6 | 2.0 | 2.2 | 1.8 | 1.7 | 1.6 | 1.1 | 1.0 | 1.0 | 1.1 | 1.0 |
| $\sigma$ | 3.0 | 1.9 | 2.4 | 2.9 | 2.4 | 2.9 | 2.8 | 2.4 | 2.0 | 1.3 | 1.0 | 1.4 | 1.0 | 1.7 | 1.4 | 0.8 | 0.9 | 0.7 | 0.7 | 0.8 |
| Nina (1935) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 6.1 | 8.3 | 8.2 | 7.2 | 6.3 | 5.4 | 4.2 | 3.6 | 4.3 | 3.3 | 3.2 | 2.2 | 2.4 | 2.0 | 1.6 | 1.8 | 1.8 | 0.8 | 0.8 | 0.7 |
| $\sigma$ | 2.6 | 2.1 | 2.6 | 2.9 | 3.0 | 3.4 | 2.2 | 2.4 | 3.0 | 3.2 | 2.4 | 1.8 | 2.0 | 2.2 | 1.4 | 1.7 | 1.7 | 1.0 | 0.8 | 0.8 |
| 3. K. Galia (1935—36) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 4.0 | 6.7 | 6.5 | 6.0 | 5.5 | 4.5 | 4.7 | 3.6 | 3.0 | 2.9 | 2.2 | 1.7 | 2.0 | 1.5 | 1.1 | 1.2 | 1.3 | 0.9 | 1.1 | 0.8 |
| $\sigma$ | 1.5 | 2.6 | 2.2 | 1.8 | 1.5 | 1.8 | 1.7 | 1.8 | 1.9 | 1.5 | 1.1 | 1.2 | 1.8 | 1.2 | 1.1 | 1.0 | 1.1 | 0.9 | 0.7 | 0.9 |
| Lucy (1935—36) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 5.2 | 7.0 | 5.5 | 5.1 | 4.1 | 4.1 | 3.8 | 3.4 | 3.5 | 3.1 | 2.5 | 2.1 | 2.5 | 1.9 | 1.6 | 1.8 | 1.5 | 1.3 | 1.6 | 1.4 |
| $\sigma$ | 2.0 | 1.4 | 1.5 | 1.3 | 1.4 | 1.5 | 1.5 | 1.5 | 1.7 | 1.5 | 1.4 | 1.2 | 1.2 | 1.0 | 0.9 | 0.8 | 1.2 | 0.9 | 1.1 | 1.0 |
| 4. L. Vera (1935) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 3.3 | 4.6 | 5.7 | 5.3 | 3.9 | 3.7 | 3.4 | 3.2 | 2.5 | 2.3 | 2.3 | 1.8 | 1.9 | 1.7 | 1.4 | 1.3 | 1.2 | 0.9 | 1.2 | 0.7 |
| $\sigma$ | 2.7 | 1.9 | 1.6 | 1.6 | 0.9 | 1.0 | 1.0 | 0.9 | 1.2 | 0.9 | 0.9 | 1.0 | 1.1 | 0.9 | 0.7 | 0.7 | 0.6 | 0.5 | 0.6 | 0.5 |
| Nadia (1935) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 3.5 | 5.5 | 5.0 | 4.9 | 3.9 | 3.9 | 3.4 | 3.2 | 3.2 | 2.7 | 2.5 | 2.4 | 2.0 | 1.9 | 1.5 | 1.5 | 1.7 | 1.7 | 1.3 | 1.2 |
| $\sigma$ | 1.4 | 1.6 | 1.0 | 0.8 | 1.1 | 1.5 | 1.0 | 1.3 | 1.3 | 1.0 | 1.1 | 1.1 | 0.8 | 1.2 | 0.9 | 1.0 | 0.9 | 0.8 | 0.9 | 1.0 |
| 5. L. Vera (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 5.8 | 9.3 | 9.5 | 8.7 | 7.2 | 5.8 | 4.7 | 4.1 | 3.7 | 3.0 | 2.9 | 2.4 | 2.0 | 2.0 | 1.4 | 1.4 | 1.2 | 1.2 | 1.0 | 1.1 |
| $\sigma$ | 2.3 | 1.3 | 1.3 | 1.4 | 1.5 | 1.8 | 1.4 | 1.2 | 1.4 | 0.9 | 1.4 | 0.8 | 0.8 | 0.9 | 0.7 | 0.5 | 0.4 | 0.6 | 0.5 | 0.5 |
| Nadia (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 4.8 | 9.5 | 9.1 | 8.3 | 7.2 | 6.0 | 5.0 | 4.4 | 3.8 | 3.8 | 3.3 | 3.2 | 2.9 | 2.2 | 2.4 | 2.4 | 2.0 | 1.6 | 1.6 | 1.4 |
| $\sigma$ | 0.9 | 1.6 | 1.7 | 1.4 | 1.5 | 0.9 | 1.6 | 1.2 | 1.1 | 1.5 | 1.1 | 1.3 | 1.3 | 0.1 | 0.9 | 1.0 | 1.1 | 0.8 | 0.6 | 0.7 |
| 6. Sm. Ghena (to cranberries) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ | 1.8 | 6.4 | 8.1 | 8.4 | 8.2 | 7.8 | 6.8 | 6.2 | 5.4 | 5.2 | 4.6 | 4.2 | 3.7 | 3.2 | 3.2 | 3.1 | 2.7 | 2.1 | 1.8 | 1.8 |
| $\sigma$ | 0.9 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | 1.7 | 1.3 | 1.1 | 1.3 | 1.1 | 1.1 | 1.5 | 1.9 | 1.1 | 1.4 | 1.0 | 0.7 | 0.8 | 0.8 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vova (to cranberries) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 3.8 | 10.6 | 10.8 | 9.9 | 9.2 | 8.0 | 8.1 | 6.0 | 6.3 | 4.8 | 5.0 | 4.2 | 3.6 | 3.1 | 2.5 | 2.1 | 1.9 | 2.3 | 1.8 | 1.6 |
| $\sigma$ . . . . . | 4.1 | 2.5 | 1.8 | 2.1 | 1.9 | 1.8 | 1.6 | 1.4 | 1.6 | 1.6 | 2.3 | 2.6 | 1.5 | 1.5 | 0.8 | 0.9 | 1.4 | 1.4 | 1.3 | 0.9 |
| 7. Sm. Ghena (to juice) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 0.5 | 2.5 | 3.3 | 4.1 | 4.4 | 4.3 | 5.4 | 5.9 | 5.2 | 4.5 | 4.0 | 3.0 | 3.4 | 2.8 | 2.7 | 2.5 | 2.0 | 1.4 | 1.5 | 1.4 |
| Vova (to juice) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 3.7 | 9.5 | 10.4 | 11.0 | 10.2 | 10.8 | 10.9 | 9.5 | 7.4 | 6.5 | 4.8 | 4.4 | 4.0 | 4.0 | 4.0 | 3.5 | 3.0 | 2.7 | 2.7 | 3.5 |
| II Group BT | | | | | | | | | | | | | | | | | | | | |
| 8. Lar. Valia (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 7.0 | 13.2 | 13.3 | 12.6 | 10.7 | 8.9 | 8.2 | 7.4 | 5.9 | 5.2 | 4.5 | 3.6 | 4.0 | 2.5 | 2.6 | 3.0 | 2.3 | 2.0 | 1.8 | 2.2 |
| $\sigma$ . . . . . | 2.1 | 1.5 | 1.7 | 1.6 | 1.6 | 1.9 | 1.8 | 1.7 | 1.7 | 2.0 | 1.7 | 1.2 | 1.5 | 1.5 | 1.5 | 1.8 | 1.1 | 1.0 | 1.2 | 1.6 |
| Nina (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 5.1 | 9.8 | 10.8 | 11.8 | 11.5 | 10.7 | 9.7 | 8.1 | 7.7 | 7.5 | 5.9 | 6.0 | 5.1 | 4.2 | 3.1 | 3.8 | 2.9 | 2.4 | 2.9 | 2.3 |
| $\sigma$ . . . . . | 1.7 | 1.6 | 1.9 | 2.1 | 1.4 | 2.1 | 1.8 | 1.7 | 2.0 | 1.7 | 1.8 | 1.4 | 1.2 | 1.4 | 1.1 | 1.1 | 0.8 | 1.0 | 1.8 | 1.9 |
| 9. B. Rid (1934) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 8.5 | 11.2 | 9.9 | 9.3 | 8.1 | 7.6 | 6.2 | 5.6 | 3.9 | 3.1 | 3.1 | 2.6 | 2.7 | 2.2 | 1.8 | 1.6 | 1.5 | 1.5 | 1.6 | 1.0 |
| $\sigma$ . . . . . | 2.1 | 2.0 | 2.3 | 1.7 | 2.2 | 2.4 | 2.3 | 2.5 | 1.9 | 1.8 | 1.8 | 1.6 | 1.6 | 1.2 | 1.3 | 1.0 | 0.8 | 1.1 | 0.9 | 0.7 |
| Donara (1934) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 6.4 | 7.6 | 6.2 | 5.9 | 5.0 | 4.1 | 3.7 | 3.0 | 2.9 | 2.5 | 2.1 | 1.8 | 1.7 | 1.6 | 1.4 | 0.9 | 1.2 | 1.0 | 0.8 | 1.2 |
| $\sigma$ . . . . . | 3.3 | 2.0 | 2.7 | 2.1 | 1.7 | 2.2 | 1.9 | 1.5 | 1.2 | 1.3 | 1.0 | 1.2 | 1.2 | 1.1 | 1.4 | 0.8 | 0.7 | 0.6 | 0.8 | 1.0 |
| 10. B. Rid (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 4.9 | 14.1 | 15.3 | 14.7 | 13.8 | 11.4 | 10.2 | 8.4 | 7.4 | 5.7 | 5.5 | 3.7 | 3.6 | 2.9 | 2.9 | 2.1 | 2.4 | 2.1 | 1.8 | 1.8 |
| $\sigma$ . . . . . | 3.0 | 3.1 | 2.6 | 2.3 | 6.7 | 3.0 | 2.8 | 2.7 | 4.0 | 3.0 | 3.0 | 1.9 | 2.0 | 2.0 | 1.8 | 1.5 | 1.7 | 1.7 | 1.5 | 1.0 |
| Donara (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 2.5 | 9.0 | 10.3 | 7.3 | 6.7 | 5.7 | 4.4 | 3.7 | 2.8 | 2.7 | 1.8 | 1.3 | 1.4 | 1.4 | 1.9 | 1.3 | 1.4 | 1.1 | 0.9 | 0.8 |
| $\sigma$ . . . . . | 1.6 | 2.1 | 2.0 | 2.1 | 2.5 | 2.4 | 2.0 | 2.1 | 1.2 | 1.4 | 1.2 | 1.2 | 1.0 | 0.8 | 1.5 | 0.9 | 1.5 | 1.0 | 0.7 | 0.6 |
| 11. M. Minna (to cranberries) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 2.8 | 8.8 | 11.6 | 11.8 | 11.2 | 9.9 | 8.0 | 6.8 | 5.1 | 4.3 | 4.1 | 3.1 | 2.7 | 2.5 | 1.3 | 1.6 | 1.5 | 1.2 | 1.1 | 1.1 |
| $\sigma$ . . . . . | 2.1 | 2.1 | 1.8 | 1.4 | 1.8 | 1.9 | 1.7 | 1.9 | 1.8 | 1.4 | 1.5 | 1.3 | 1.0 | 1.1 | 0.6 | 0.9 | 0.9 | 0.8 | 0.5 | 0.5 |
| Ella (to cranberries) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 5.2 | 10.2 | 12.6 | 12.0 | 9.7 | 7.3 | 5.6 | 5.3 | 4.3 | 3.6 | 2.7 | 2.1 | 2.1 | 1.5 | 1.6 | 1.3 | 1.3 | 1.3 | 0.9 | 1.3 |
| $\sigma$ . . . . . | 3.0 | 1.9 | 1.6 | 2.0 | 1.6 | 2.1 | 1.8 | 1.9 | 1.4 | 1.4 | 1.0 | 1.0 | 1.2 | 1.0 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 1.0 |
| 12. M. Minna (to juice) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 2.4 | 9.0 | 9.5 | 9.5 | 8.7 | 8.6 | 8.0 | 6.9 | 5.3 | 3.8 | 3.5 | 2.8 | 2.1 | 2.4 | 1.5 | 1.6 | 1.3 | 1.4 | 1.3 | 1.1 |
| $\sigma$ . . . . . | 2.3 | 2.1 | 1.9 | 1.6 | 2.5 | 2.0 | 2.2 | 2.3 | 2.1 | 1.7 | 1.6 | 1.8 | 1.4 | 1.4 | 1.2 | 1.5 | 1.0 | 1.2 | 0.8 | 1.0 |
| Ella (to juice) (1937) | | | | | | | | | | | | | | | | | | | | |
| $\bar{X}$ . . . . . | 2.4 | 5.3 | 5.0 | 5.3 | 5.8 | 5.7 | 6.1 | 5.8 | 5.3 | 3.6 | 2.9 | 3.0 | 2.9 | 2.1 | 1.5 | 2.2 | 1.6 | 1.1 | 1.3 | 1.5 |
| $\sigma$ . . . . . | 1.4 | 1.5 | 1.3 | 1.5 | 2.4 | 1.5 | 1.8 | 2.7 | 1.6 | 1.5 | 1.5 | 1.6 | 1.6 | 1.5 | 1.2 | 1.2 | 1.1 | 0.8 | 1.3 | 1.2 |

Only further experimental studies under in-patient conditions may aid us in throwing light on these in a certain sense «character forming» factors of the surrounding medium.

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*PHYSIOLOGY*

# CONDITIONED SALIVARY REFLEXES IN HUMAN TWINS. III

By I. KANAEV

*(Communicated by L. A. Orbeli, Member of the Academy, 16. VII. 1939)*

Two properties of conditioned reflexes are to be dealt with in the present article: the extent of the conditioned reflex, expressed in drops of saliva obtained from both gl. parotis during 30 sec., and the rate of the arising of the conditioned reflex, i. e. the time interval from the beginning of the tests, which is necessary for the sure formation of a conditioned relation. not disappearing in the subsequent tests.

The study was conducted on 8 pairs of twins of school age, of which 5 were unioval (UT) and 3—bioval (BT). The saliva was collected by the method of Krasnogorsky, in whose laboratory this study was started, and the secretion recorded on the tape of a cymograph. The material obtained was partly subjected to a statistical treatment.

The extent of the conditioned reflex was sometimes found to be highly variable: the number of drops during 30 sec. varied both in the course of one test day and from one day to the other. This phenomenon, stated already long ago, showed differences within each of the pairs studied, being not smaller and sometimes even greater in the unioval than in the bioval twins. Thus, for instance, in the bioval pair of twins B. (a boy and a girl) the difference in favour of the boy was 43 drops in the course of 12 test-days, while in the unioval pair S. (boys) the difference for 12 days was 119 drops, i. e. considerably greater. One of these twins, Vova, showed nearly always a higher conditioned secretion, than the other boy (Ghena). As an illustration I shall cite the numbers of drops for 7 subsequent days.

| March 1937 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|
| Ghena . . . . . | 3 | 5 | 19 | 18 | 14 | 24 | 15 |
| Vova . . . . . | 3 | 10 | 19 | 19 | 24 | 20 | 28 |

Of course, there are pairs of UT, in which this difference is quite small. Thus, e. g., in the girls K.: only 17 drops in 12 days. It is essential that the higher secretion of one of the twins of a pair is a phenomenon which shows a tendency to last for a long time, for months or even years. In other words, higher conditioned secretion is a kind of a characteristic functional peculiarity of the nervous system of the child.

It is worth noting that within the limits of one test-day the secretion caused by the first conditioned stimulation is smaller, than the one caused by the second stimulation. This is visible, e. g., from the mean values ($X$) and their mean square deviations ($\sigma$) for the number of drops obtained during a series of tests on one pair of UT—In. (experiments of 1938).

| | $\bar{X}$ | $\sigma$ | | $\bar{X}$ | $\sigma$ |
|---|---|---|---|---|---|
| T. 1st stimul. . . . . | 4.0 | 3.4 | N. 1st stimul. . . . . | 3.0 | 2.0 |
| 2nd » . . . . . | 9.2 | 3.6 | 2nd » . . . . . | 6.4 | 4.5 |

The child appears as if it were «attuned» only by the second conditioned stimulation. During the first it is, probably, still under the influence of various preceding impressions.

From the means cited above we see in this pair of UT also a rather considerable difference. A number of quite noticeable differences in the conditioned reflexes of this pair in the course of experiments with depression and the «law of force» has been already described earlier (1934 and 1937)([1],[2]).

The reason which may be put forward to account for the existence of considerable differences within a pair of UT (and in the UT pair Sm. even much greater than in some BT), is that the extent of the conditioned reflex is essentially determined by the environmental factors, and the manifestation of the genotypical factors in this process is therefore greatly complicated. It would seem, that the extent of the conditioned reflex cannot be made the basis for decisions on the strength or weakness of the nervous system, unless due consideration of the importance of the various enivironmental factors affecting the reflex is possible.

A somewhate different picture becomes clear as the result of studying the r a t e o f a r i s i n g of the conditioned reflex. In four pairs of UT out of five the conditioned reflex was formed, beyond any doubt, on the same day, and only in one pair of UT there was one day divergence. In the BT, to the contrary, the difference in the rate at which the conditioned reflex had been established was very distinct, it formed at a different rate in different children. These facts must be evidently interpreted in the sense that the rate of the formation of the conditioned reflex is in a great measure determined by the genotype, which is identical in the UT and differs in the BT. However, this process also depends on the influence of the surroundings, which may give rise in this case as well to dissimilarities within one pair of UT, as e. g. we observed in our 5th pair. The causes of this dissimilarity may be such as disease, fatigue, fright and similar conditions, provoked by factors of the surrounding medium and interfering with the formation of conditioned relations.

It is very likely that the rate of the formation of conditioned relations (i. e. the time they take to form from the beginning of the tests to their clear manifestation) is a simpler process than the intensity of conditioned salivation which is bound with some other processes in the nervous system. The more complicated the process,the stronger seems to be its dependence upon the environment and the life history of the individual. Something similar to this we have already seen when comparing spontaneous and unconditioned secretion.

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*PHYSIOLOGY*

# CONTRIBUTION TO THE STUDY ON THE CORRELATION BETWEEN SPONTANEOUS, CONDITIONED AND UNCONDITIONED SALIVARY SECRETION IN ONE PAIR OF UNIOVAL TWINS. IV.

By I. KANAEV and N. BOROVKA

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Attempts to solve the problem of the interdependence between conditioned and unconditioned secretion have been made repeatedly by the Pavlov school, but the various authors came to contradictory conclusions. In none of these studies which were arranged on dogs and on children, the problem was approached statistically, this alone representing the eventual cause of a certain lack of precision and of the unconvincing character of some of their conclusions.

In the present work a series of tests was arranged in 1938 on the lines of Krasnogorsky's method on a pair of unioval twins In. of school age, of which one of us has already written in 1934 and 1937. The scheme of the tests was as follows: spontaneous secretion from both gl. parotis recorded during 10 min.; this is followed by conditioned stimulations (metronome) continuing for 30 sec. each at 4—5 min. intervals and strengthened by sugar-coated cranberries. From these tests the following data were registered: the number of drops of spontaneous saliva secretion during the 10 min. preceding the test proper, the number of drops of conditioned secretion during 30 sec. (the term of action of the conditioned stimulus) for the first and second conditioned stimulation, and, finally, the number of drops during 50 sec. of unconditioned secretion from the moment of the administration of food as a strengthening stimulus after the first and second conditioned stimulations.

The correlation was calculated for spontaneous secretion, on the one side, and the first conditioned or the second conditioned, and the first unconditioned or the second unconditioned secretion respectively, on the other; and, finally, for the first conditioned and the accompanying unconditioned secretion and similarly for the second conditioned and unconditioned secretions.

Moreover, for three figures the general coefficient of correlation and two partial ones were calculated. The general coefficient of correlation measures the joint action of quantities on a third. In our case it expresses the joint action of the factors determining the spontaneous and unconditioned secretion on the conditioned one. In other words, it shows in what measure conditioned secretion, being bound with unconditioned and spontaneous secretion, depends on both taken together.

The partial coefficient of correlation determines the relation between two values if the third one is constant. In other words, if we mentally assume this third quantity, e. g. spontaneous secretion, to take a certain value, e. g. 50 drops in a certain interval of time, and on the basis of all the concrete data corresponding to this assumption calculate the simple coefficient of correlation in our example, for the conditioned and the unconditioned secretion, we obtain an approximative expression of the partial coefficient of correlation for unconditioned and conditioned secretion, when spontaneous secretion is constant ($_sr_{uc}$).

We took about 15 figures for every kind of secretion for each twin—a relatively small number. The results are summarized in the following table, in which $r_{sc}$ signifies the coefficient of correlation between spontaneous and conditioned secretion, $r_{su}$ — the coefficient of correlation between spontaneous and unconditioned secretion, $r_{uc}$ — that between unconditioned and conditioned secretion. Line I contains the values of $r$ for the first conditioned and unconditioned stimulations, line II—those for the second. Moreover, the general coefficient of correlation is designated by $R_{r,\ su}$, the two partial coefficients—by $_sr_{uc}$ and $_ur_{sc}$. The existence of a connexion between conditioned and unconditioned secretion, on the one hand, and conditioned and spontaneous secretion, on the other, is particularly apparent from these two coefficients.

The values of the coefficients of correlation recorded in this table should be considered as somewhat understated, since in calculating them the correlated quantities were assumed to stand in a rectilinear relation to one another, while in reality this relation between the three kinds of secretion is curvilinear to some degree or other; if, for instance, the spontaneous secretion grows, the average conditioned secretion does so at an increasing rate.

Each value of the coefficient of correlation is followed by its respective error.

| | | $r_{sc} \pm \sigma_r$ | $r_{su} \pm \sigma_r$ | $r_{uc} \pm \sigma_r$ | $R_{c,su} \pm \sigma_R$ | $_sr_{uc} \pm \sigma_r$ | $_ur_{sc} \pm \sigma_r$ |
|---|---|---|---|---|---|---|---|
| Tamara | I | +0.51 ±0.20 | +0.46 ±0.21 | +0.53 ±0.19 | +0.61 ±0.17 | +0.52 ±0.20 | +0.47 ±0.21 |
| | II | +0.33 ±0.23 | +0.23 ±0.25 | −0.07 ±0.26 | +0.36 ±0.22 | −0.16 ±0.25 | +0.35 ±0.22 |
| Nina | I | +0.70 ±0.13 | +0.08 ±0.26 | −0.28 ±0.24 | +0.78 ±0.10 | −0.68 ±0.14 | +0.79 ±0.10 |
| | II | +0.37 ±0.25 | +0.09 ±0.26 | +0.15 ±0.26 | +0.39 ±0.23 | +0.13 ±0.26 | +0.36 ±0.23 |

A comparison of the figures of this table allows to draw the following conclusions:

1. There exists a doubtless correlation between spontaneous secretion and conditioned secretion. It is very distinct during the first stimulation and quite immaterial during the second conditioned stimulation. In other words, a readily noticeable functional rearrangement of the nervous system occurs after the first conditioned stimulation.

2. There seems to be no correlation between spontaneous and unconditioned secretion with the exception of the first unconditioned stimulation in Tamara, in whom spontaneous secretion is in general quite considerable.

3. There is no correlation between conditioned and unconditioned secretion, with the exception of the first stimulation in Tamara. A rather obscure hint at a negative correlation in some instances demands further investigation.

4. A very interesting difference is noted between the coefficients of correlation in both twins, particularly in respect of spontaneous and first conditioned secretion: it is greater in Nina than in Tamara. It possibly reflects

the greater inertness of Nina, observed in everyday life. This difference, as well as other differences noted earlier in this pair of twins, is probably determined by differences in the action of the surroundings and in the individual life-history of each of the girls.

The experimental part of this work and the initial treatment the data obtained in the experiments have been made by Kanaev, the coefficients of correlation have been calculated by Borovka.

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*GENETICS*

# KARYOSYSTEMATIC STUDY ON CULTIVATED AND WILD OATS

By E. M. SHEPELEVA

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Chromosome morphology was studied in the diploid (*A. strigosa*, $n=7$, *A. hirtula*, $n=7$), tetraploid (*A. barbata*, $n=14$, *A. abyssinica*, $n=14$, *A. vaviloviana*, $n=14$) and hexaploid (*A. sativa*, $n=21$, *A. fatua*, $n=21$, *A. byzantina*, $n=21$) forms of oats (sectio *Eu-avena*).

Rootlets were fixed in a mixture of 10% formalin with 1% chromic acid solution (1). Chromosome differentiation was so clearly revealed by this fixation, that it proved possible to establish rather exactly the idiograms in all the forms investigated and to follow up the recurrence of the chromosomes of diploids in forms possessing higher chromosome numbers. Chromosome measurements were made with the aid of Levitsky's method (1); the idiograms reported in this paper were prepared on the basis of numerical data.

Fig. 1. Idiograms of the diploid and tetraploid forms of *A. strigosa*. A—ssp. *strigosa* subvar. *sesquialtera*; B — ssp. *hirtula*; C — ssp. *barbata*; D—ssp. *abyssinica*.

All the 14-chromosome forms investigated are phylogenetically closely related to one another. Karyological data fully confirm the affinity among them, as their idiograms are very similar (Fig. 1, A, B). Twenty-eight chromosome forms, in their turn, have much in common with the diploids. Morphologically *A. hirtula* and *A. barbata* are especially near akin, which is also fully confirmed by the chromosome morphology (Fig. 1, B, C). In the set of *A. barbata* there are ten chromosome pairs which are similar to chromosomes of *A. hirtula* and *A. strigosa* (I—V, VIII—XII), one chromosome (VII) with the ratio of arms 1 : 2.5 characteristic of diploids is lacking here, and two types (in 4 pairs) appear to be new (VI, VII, XIII, XIV).

One may conclude from the idiogram of *A. barbata* (Fig. 1, C) that the chromosome set of this species consists of two closely related genomes which differ only in a single chromosome (I and VIII). As reduction division in

the hybrid *A. barbata* × *A. strigosa* has been rather well studied ([2], [3]), an attempt was made to bring in accord the data obtained by us with the behaviour of chromosomes in reduction division. In the reduction division of the hybrid *A. barbata* × *A. strigosa* there are usually formed seven compact bivalents, however there are sometimes observed eight and on rare occasions nine bivalents. When univalents are associated with them, 1—5 trivalents arise; there occur sometimes four-fold groups of the open type which are probably formed by association of the eighth bivalent to the one of the seven principal ones. Nishiyama ([2]) concludes from these formations that *A. barbata* contains a whole genome of *A. strigosa*. However, *A. barbata*, as we have seen, possesses only six morphological chromosome types of *A. strigosa*, whereas the seventh is absent or strikingly modified.

In order to show clearer which chromosomes may pair in reduction division I resort to the scheme worked out by Nishiyama to explain the data on chromosome behaviour in meiosis of the hybrid as just referred to. The chromosomes are simply designated by letters; identical letters in the two species crossed would mean their homology as decided upon on the basis of conjugation. Instead of these conventional symbols I have introduced into the Nishiyama's scheme real chromosomes, all of which have there found their respective places; verification and concreteness of the scheme were thus attained (Fig. 2). Chromosomes of *strigosa* are designated by numerals (I—VII), the chromosomes of *barbata* which are morphologically similar to them—with the same numerals, whereas the morphologically different chromosomes are designated with the letters $b_1$ and $b_{11}$.

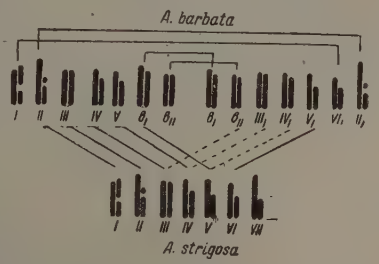


Fig. 2. A diagram of interrelations among the chromosomes of *Avena barbata* and *A. strigosa*, both relative to morphology and conjugation in meiosis.

As chromosome morphology has shown that in *A. barbata* six chromosome pairs recur twice (Fig. 1, C), the most natural idea is that *A. barbata* contains two genomes which are very closely related to each other and differ only in a single chromosome pair (I and VI), as shown in the scheme of Fig. 2. Then five bivalents will be formed through autosyndesis of the *A. barbata* and *A. strigosa* chromosomes (I, II, III, IV, V) and two—through intergenome autosyndesis in *A. barbata* ($b_1$, $b_1$ and $b_{11}$, $b_{11}$). Four trivalents arise through association of the chromosomes of the second genome of *barbata* (II, III, IV, V) to the analogous bivalents. The chromosome VI of the second genome of *A. barbata* is morphologically similar to the VI chromosome of *A. strigosa* and, very probably, can conjugate with it under formation of the eighth bivalent. We consider this chromosome to be a modified chromosome (I) of the first genome; it is possible, therefore, that it still has regions homologous to those of the latter and is able to conjugate with it under formation of a trivalent or a quadripartite association. The ninth bivalent arises extremely rarely and is losely bound; probably, one should admit the possibility of its formation at the expense of association of a *strigosa* chromosome (VII) to another morphologically different chromosome *barbata*, although morphologically homologous, at least in part*.

* Following Nishiyama's scheme ([3],[4]) all the 7 basic bivalents are formed by allosyndesis, whereas the 8th and 7th—through intergenome autosyndesis. The modification of the Nishiyama scheme appears to us to be more correct as it is based not only on chromosome conjugation, but on their morphology, too.

It may be seen from the above said that *A. barbata* may be karyologically regarded as to be an autotetraploid which suffered modification of the one chromosome (VI). However, this may be at variance with the fact that the VI chromosome of the second genome of *barbata*, which was regarded by us as being a modified I chromosome of the first genome, is morphologically similar to a chromosome (VI) of *strigosa* and probably is able to form a bivalent with the latter, which may point to another origin of this chromosome, and, consequently, of the whole of the second genome. However, the same chromosome (VI) has some homologous regions in common with the original chromosome (I), as it forms with it a bivalent or a tetravalent, which on the contrary testifies to the affinity of the two genomes of *barbata*. In the reduction division of *barbata* there are always formed 14 bivalents ([2]) and no quadrivalents are ever observed. Formation of 4—7 quadrivalents was observed in *Avena elatior* ([4]), as well as in a tetraploid plant in the progeny of a hybrid *A. barbata* ×*A. strigosa*. Formation of quadrivalents in *barbata* could be expected merely from the presence of trivalents and quadriva-

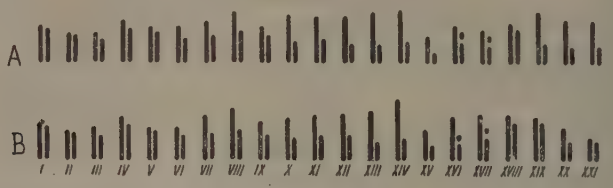


Fig. 3. Idiograms of the hexaploid forms: A—*A. fatua*; B—*A. sativa*

lents in the hybrid *A. barbata* × *A. strigosa*, and their absence should be explained through the ability of chromosomes to behave differently under different conditions ([5]). When closely related chromosomes are present, there occurs a more complete conjugation in pairs and no multivalent associations are observed. It is probable, therefore, that *A. barbata* was nevertheless formed through doubling of the chromosome number in a species very closely related to *A. strigosa*. This species, which possibly does not exist any more, evidently gave origin to *strigosa* and *barbata*, although their evolution proceeded along different ways.

The idiograms of the remaining two tetraploid forms somewhat differ from that of *A. barbata*, but are similar to each other, inasmuch as one may judge by several characteristic chromosomes. Only *A. abyssinica* was subjected to a more detailed study. Its idiogram which has been exactly established (Fig. 1, D) has shown that the chromosome set of *A. abyssinica* consists of two different genomes, one of which is probably very similar to the genome of *strigosa* or *hirtula*. This points to the affinity of *A. abyssinica* with diploid forms and, consequently, testifies to their common origin.

All the hexaploid forms stand apart from the diploid and tetraploid forms; they belong to another subsection (*Denticulatae*). The two subspecies of *A. fatua* reported here (*fatua* and *sativa*) are so close to each other both taxonomically and genetically, that one might expect full similarity with respect to chromosome morphology. The idiograms (Fig. 3) have shown, however, that only 18 chromosome pairs are similar in *A. sativa* and *A. fatua*, whereas three pairs (XIX, XX, XXI) greatly differ in appearance. However, usual formation of a full number of bivalents in the reduction division in the hybrid *A. fatua* ×*A. sativa* ([2]) shows that these morphologically different chromosomes are able to conjugate somehow with one another.

Probably, these chromosomes are related to one another inspite of significant morphological differences among them.

The third subspecies, *A. byzantina*, belongs to another species, *sterilis*. It has been studied rather slightly, but it was found that all the typical easily distinguishable chromosomes of *fatua* and *sativa* recur in this subspecies, too. On this ground one can conclude that the two species belonging to subsection *Denticulatae* possess common genomes and are closely related to each other.

In order to judge upon the affinity of the two subsections *Denticulatae* and *Aristulatae* on the basis of karyological data one should investigate the hexaploid forms in more detail and in a greater number of representatives; this proved as yet to be impracticable, owing to the great labour involved. One may just remark that while a number of chromosomes are similar (especially the most typical satellited ones), the idiograms of the subsection *Denticulatae* markedly differ from those of *Aristulatae* in having a great number of strongly heterobrachial chromosomes, which fact demonstrates a rather remote relation between these two subsections.

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*GENETICS*

# KARYOTYPES OF POLLEN GRAINS IN TRIPLOID *CREPIS CAPILLARIS* WALLR.

By N. CHUKSANOVA

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Triploids are known to occur in a great number of plant species. Their characteristic feature is a high sterility ([5],[7],[9],[11]). In the progeny of triploids there should be formed diploids, triploids, simple, double and other trisomics. According to the recombination theory, trisomics should be, besides, far more numerous than diploids and triploids. In meiosis the chromosomes which are distributed at random compose at the second metaphase plates containing all the chromosome numbers ranging from the haploid to the diploid one with expected frequencies ([3], [6]). It is nevertheless known that triploid plants are far from producing all the expected forms. Thus, in the progeny of triploid tomatoes the most frequent forms among trisomics are the 25-chromosome ones, i. e. the simple trisomics ($2X+1$), and no plant was ever found with a chromosome number exceeding $2X+3$ ([4]). On the other hand, in the triploid petunia self-pollination produced only $2X+5$, 6, 7-chromosome forms ([3], [6]). In triploid *Crepis capillaris* are formed mainly triploids (28.8%) and diploids (63.9%), whereas there arise only 3% of trisomics ([8]). Only a few of the theoretically expected chromosome combinations are thus realized.

It seemed of interest to find out whether or not the reason lies in a lower vitality of certain chromosome combinations in pollen grains.

One usually judges of the gametes formed by the progeny or by chromosome counts in the second metaphases in meiosis. However, this sort of judgement does not distinguish between gametic and zygotic sterility, and chromosome numbers in metaphases give no idea of the actual chromosome combinations in pollen grains formed. Besides, each chromosome possesses specificity, and it is possible that gametes with definite karyotypes are less frequent than others; when only numbers of chromosomes are considered, this difference in the frequency is levelled.

We attempted to find out in our study whether or not all the karyotypes are equally frequent in pollen grains. *Crepis capillaris* proved to be the most suited material for this purpose. Its chromosomes are few in number ($2X=6$) and each of them is morphologically distinguishable. *A*—a large heterobrachial chromosome, *D*—smaller chromosome with a satellite, *C*—small chromosome with the second arm in the form of a head.

G. A. Levitsky has obtained in the Laboratory of Cytology at the Pushkin Branch of the All-Union Institute of Plant Industry triploid mutants of *Crepis capillaris* ($3X=9$) by X-raying. They served as a material for our work. The aceto-carmine method was applied.

Following the permutation theory *Crepis capillaris* should produce 8 types of gametes of equal frequency. We have studied in the triploids No. 1720 and No. 1714 metaphases of the first pollen grain division. The

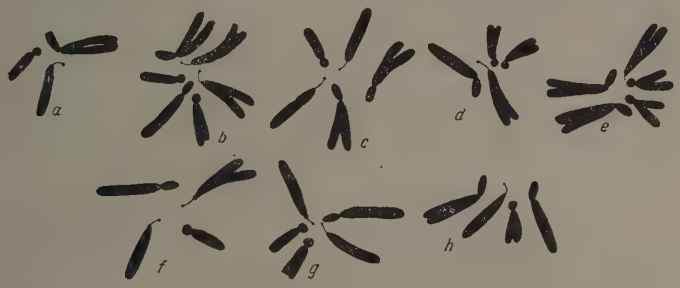


Fig. 1. Karyotypes of the pollen grains at the first division: a) *ADC*, b) 2*ADC*, c) *ADC*+*AD*, d) *ADC*+*C*, e) *ADC*+*AC*, f) *ADC*+*D*, g) *ADC*+*DC*, h) *ADC*+*A*.

data obtained are summarized in Table 1. It shows that all the theoretically possible karyotypes, from the haploid to the diploid, are found in the pollen grains at the first division, whereby the frequency of the majority of the types is well within the limits of expectation (Fig. 1).

Table 1

Karyotypes at the 1st Division in the Pollen Grains of Triploid *Crepis capillaris* under Normal Conditions

| Karyotypes | Plant No. 1720 | | | | | Plant No. 1714 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Observed | | Expected, % | Difference, % | $\frac{D}{m}$ | Observed | | Expected, % | Difference, % | $\frac{D}{m}$ |
| | number | % | | | | number | % | | | |
| 2 *ADC* . . | 15 | 6 | 12.5 | −6.5 | 4.3 | 17 | 6.74 | 12.5 | −5.76 | 3.66 |
| *ADC* . . . | 39 | 15.6 | 12.5 | +3.1 | 1.4 | 47 | 18.65 | 12.5 | +6.15 | 2.51 |
| *ADC* + *AD* | 36 | 14.4 | 12.5 | +1.9 | 0.85 | 39 | 15.47 | 12.5 | +2.97 | 1.30 |
| *ADC* + *C* . | 23 | 9.2 | 12.5 | −3.3 | 1.8 | 29 | 11.54 | 12.5 | −0.96 | 0.42 |
| *ADC* + *AC* | 31 | 12.4 | 12.5 | −0.1 | 0.048 | 14 | 5.56 | 12.5 | −6.94 | 4.80 |
| *ADC* + *D* . | 38 | 15.2 | 12.5 | +2.7 | 1.2 | 36 | 14.28 | 12.5 | +1.78 | 0.80 |
| *ADC* + *DC* | 35 | 14 | 12.5 | +1.5 | 0.68 | 35 | 13.88 | 12.5 | +1.38 | 0.63 |
| *ADC* + *A* . | 33 | 13.2 | 12.5 | +0.7 | 0.32 | 35 | 13.88 | 12.5 | +1.38 | 0.63 |
| Total . | 250 | 100 | 100 | | | 252 | 100 | 100 | | |

Diploid pollen grains are decidedly less numerous. Thus, in No. 1720 the ratio of diploid pollen grains to haploid ones is approximately 1 : 2, and in No. 1714 diploid pollen grains are still less numerous, the ratio being approximately 1 : 3. The frequency of some of the other types of pollen grains with additional chromosomes also somewhat deviate from the expected one. However, the deviation is significant only in the case of the pollen grains with the karyotype *ADC*+*AC*, in No. 1714.

On the basis of these data it is impossible to say anything about the viability of the different karyotypes of the pollen grains, as the frequency of

occurrence of nearly all of them lies within the limits of expectation; deviations which were discussed above cannot account for rare occurrence of trisomics in the progeny of triploids. Inspection of pollen at the stage of the first division has revealed no greater proportion of sterility than that typical of the triploids.

It would seem possible to study the comparative vitality of pollen by placing pollen development under less favourable conditions, for example, under the influence of reduced temperature. In case all of them possess equal vitality, they will react to the change of conditions in an identical manner, i. e. the frequency of pollen grains with different karyotypes will drop in equal degree. In case they differ in viability, the frequency of those which are less viable would be stronger reduced.

One of the plants (No. 1720) still continued flower-bud formation at the middle of September when the conditions were less favourable owing to lower temperature. It thus proved to be possible to make the desired trial of the pollen grains with regard to their vitality.

116 pollen grains at the stage of first division were inspected. They presented the following aspect (Table 2): pollen grains with extra chromosomes proved to be significantly less numerous than it should be expected, with the exception of those possessing *AD* and *A* extra chromosomes; they were somewhat more numerous, but significantly less numerous than the haploid ones. Diploid pollen grains showed the original ratio to diploid ones, i. e. 1 : 2, which occurred before under favourable conditions.

Table 2

Karyotypes at the 1st Division in the Pollen Grains of Triploid *Crepis capillaris* under Unfavourable Conditions

| Karyotypes | Plant No. 1720 | | | | |
|---|---|---|---|---|---|
| | Observed | | Expected, % | Difference % | $\frac{D}{m}$ |
| | number | % | | | |
| 2 *ADC* . . . . . | 18 | 15.5 | 12.5 | + 3.0 | 0.89 |
| *ADC* . . . . . | 38 | 32.7 | 12.5 | +20.2 | 4.6 |
| *ADC* + *AD* . . . . . | 20 | 17.2 | 12.5 | + 4.7 | 1.34 |
| *ADC* + *C* . . . . . | 5 | 4.3 | 12.5 | — 8.2 | 4.36 |
| *ADC* + *AC* . . . . . | 5 | 4.3 | 12.5 | — 8.2 | 4.36 |
| *ADC* + *D* . . . . . | 6 | 5.2 | 12.5 | — 7.3 | 3.5 |
| *ADC* + *DC* . . . . . | 8 | 6.9 | 12.5 | — 5.6 | 2.5 |
| *ADC* + *A* . . . . . | 16 | 13.8 | 12.5 | + 1.3 | 0.4 |
| Total . . . . . | 116 | 100 | 100 | | |

It thus appears to be clear that pollen grains with extra chromosomes are distinguished in *Crepis capillaris* by decreased viability. Under favourable conditions they are still preserved at the first division in a more or less normal proportion, whereas under unfavourable conditions we find at the same stage only 51.8% of them instead of the expected 75%. Consequently, as much as 23.2% of them degenerate toward the beginning of the first division. Further on the remaining pollen grains with the extra chromosomes probably degenerate, too. Instances of degeneration of the generative nucleus and sperms were found.

At maturity when sperms are formed, counts of empty degenerated pollen developed under favourable conditions have shown in normal *Crepis capillaris* 5.8% of sterility, in the triploid No. 1720—42.2%, in No. 1714—52.6%.

whereas theoretically, on the assumption that all the pollen grains with extra chromosomes are unviable, the proportion of sterile pollen in triploids should be expected to amount to about 81% (75+5.8). It may be concluded from this that under favourable conditions some of the pollen grains with additional chromosomes may be viable and functional. Under unfavourable conditions when flower-buds were formed in September, in the triploid No. 1720 there were found 79.7 % of sterile pollen which very closely approached to the percentage (80.8) expected on the assumption that all the pollen grains with supernumerary chromosomes were unviable.

Counts have shown that there were 97.3% of empty seeds in the triploid No. 1720 and 98.9% in the triploid No. 1714, whereas 36.3% of sterile seeds were found in the normal *Crepis capillaris**.

In triploids as compared with normal plants there were thus more than 60% of ovules incapable of development, which probably should be attributed to the unviability of gametic or zygotic combinations with an excess of chromosomes. At any rate, as pointed out above, only triploids and diploids are formed by a triploid pollinated by diploids. However, from the fact that certain pollen grains with supernumerary chromosomes (for example, $ADC+AD$ and $ADC+A$) are formed in a sufficient amount even under unfavourable conditions, one may take it for possible that under certain conditions trisomics may be also obtained in the progeny of a triploid *Crepis capillaris*. Thus, M. Navashin ([9]) succeeded in obtaining 3% of trisomics triplo-*A*, triplo-*D*, triplo-*AC*, triplo-*DC* and triplo-*AD*. Only triplo-*C* were not obtained at all.

The constancy of the ratio of the diploid pollen grains to the haploid ones both under favourable and unfavourable conditions speaks for their sufficient viability.

The ratio of diploid pollen grains to haploid ones (1 : 2, 1 : 3) cannot be explained through degeneration of diploid pollen grains, as otherwise it should not remain unchanged under unfavourable conditions. It may be thought that this ratio is a result of chromosome lagging at meiosis, which was repeatedly pointed out in literature ([1,3,5]).

M. Navashin ([9]) has pointed out that in the triploid *Crepis capillaris* when pollinated by diploids, triploids and diploids are formed in the ratio 1 : 2 (2*X*—66.7%, 3*X*—31.4%), instead of the expected 1 : 1. To explain this ratio he has made a suggestion «whether or not chromosome lagging» may account for it. Our data show that this ratio of diploids to triploids in the progeny of triploids (pollinated with the pollen of diploids) should be explained by the ratio of diploid and haploid egg-cells, which, in its turn, should be a result of chromosome lagging. As a matter of fact, if the gametes in question are formed in the 1 : 2 ratio, the ratio of triploids and diploids in the progeny of an open pollinated triploid should be 1 : 2.

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* No seeds were obtained from the inflorescences which were at bud stage in September, as all the flowers were used for determination of karyotypes in the pollen grains.

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*GENETICS*

# INDUCTION OF DIRECTED MUTATIONS IN *DROSOPHILA*

By S. GERSHENSON

*(Communicated by N. I. Vavilov, Member of the Academy, 4. VI. 1939)*

Darwin classified all hereditary variations which furnish material for natural and artificial selection into two main types—definite and indefinite variations. Under the former he understood variations arising as a result of a specific reaction of the organism in response to some influence of the environment; under the latter, such variations, the origin of which cannot be immediately connected with the action of a definite external factor. According to his point of view, both types of variations play a rôle in evolution, though indefinite variations are much more significant in this respect than definite ones. Since Darwin numerous attempts were made to obtain definite hereditary variations experimentally. A number of investigators tried to prove the possilility of inheritance of adoptive acquired characters. These works ended in a complete failure, and at present it is evident that the idea on which they were based is fundamentally erroneous. Other investigators attempted artificially to obtain directed, but not necessarily adaptive mutations. Such attempts were especially enhanced by the discovery of Muller that usual (random) mutations can be induced by means of X-ray treatment. The work along this line, however, met with no definite success either. Quite recently Blakeslee and a number of other geneticists made a step towards the solution of the problem by showing the possibility of specific induction of polyploid mutations in plants under the influence of chemical treatment (colchicine, acenaphthene). Nevertheless, directed gene mutations, most significant from the evolutionary standpoint, were never obtained experimentally, and some geneticists even grew sceptical as to the possibility of producing such a result.

From theoretical considerations about the nature of chromosomes and in view of some facts concerning the rôle of nucleic acid in the manifestation of hereditary characters (mosaicism), we have fixed our attention on this substance. Sodium salt of thymo-nucleic acid was obtained (after Neumann) from calf thymus glands and was fed to *Drosophila melanogaster* larvae. A sublethal dosage was applied, i. e. a 5% solution of this salt in the usual yeast medium used in rearing these flies. Flies from four different stocks were treated—$w^a$, *y pn*, *yw fB*/*sc vf* and *w*. The work was carried throughout with individual pairs, each pair giving offspring in two vials—the first containing the usual medium (control) and the second, a medium added with the sodium salt of thymo-nucleic acid. The results were similar in all the

four experiments. A large proportion of larvae and pupae perished, and among the emerging flies a considerable number of variations was observed (Table 1).

Table 1

| Stock | Control | | | Experiment | | |
|---|---|---|---|---|---|---|
| | Number of cultures | Number of flies | Variations | Number of cultures | Number of flies | Variations |
| $w^a$ . . . . . | 3 | 181 | None | 3 | 38 | 2 ♂ crossveinless, 1 ♀ beaded wings |
| *ywfB/scvf* . . . | 4 | 351 | 2 ♀, 1 ♂ abnormal abdomen | 6 | 78 | 6 ♀, 4 ♂ shortened *L*5, 2 ♀ beaded wings, 1 ♂ crossveinless. 3 ♀, 4 ♂ abnormal abdomen |
| *y pn* . . . . . | 3 | 108 | 2 ♀ abnormal abdomen | 10 | 129 | 1 ♂ shortened *L*5, 2 ♂ crossveinless, 2 ♂ beaded wings, 1 ♀, 1 ♂ dachs legs |
| *w* . . . . . | 20 | 1 268 | 1 ♂ abnormal abdomen | 25 | 845 | 6 ♀, 9 ♂ shortened *L*5, 8 ♀ beaded wings, 3 ♀ beaded wings and shortened *L*5, 2 ♂ *Bx*-type, 6 ♀, 1 ♂ abnormal abdomen, 1 ♂ deformed eyes |

The data summarized in Table 1 show that the treatment used in our experiment induces a number of «morphoses» of a specific nature. Among them first of all should be mentioned the appearance of beaded wings* and the shortening of the 5th longitudinal vein. Somewhat less frequent were variations of the crossveinless type and dachs legs. Other variations (deformed eyes and abnormal abdomen) cannot be with certainty attributed to the influence of experimental treatment, as the former was met only in a single individual and the latter (though much more rarely) was found also in the control.

All the aberrant flies from the experimental cultures were mated to their sibs. Moreover, a number of normal sibs were inbred in the experimental and in the control series. In the offspring of the control flies no hereditary variations were found in a total of 208 crosses. In the experimental series in 13 crosses out of 228, i. e. in about 5%, mutations were found (Table 2).

The mutations found in the experimental series belong only to a few types. Most frequently (7 cases) arose a mutation of the *Beadex*-type—a sex-linked

* In 1938 Tarnovsky in our laboratory obtained under the influence of nucleic acid several *Bx*-like flies, which were not studied further. Probably, their nature was similar to those obtained by us.

Table 2

| Stock | Control | | Experiment | |
|---|---|---|---|---|
| | Number of crosses | Mutations | Number of crosses | Mutations |
| *yw\|B\|scvf* . | 26 | None | 21 | 1 case of crossveinless (bunch) |
| *y pn* . . . | 20 | » | 19 | 1 case of plexoid (bunch), 1 case of *Beadex*-type |
| *w* . . . . . | 162 | » | 188 | 6 different cases of *Beadex*-type (5 bunches), 3 different cases of crossveinless, 1 case of broad-dachs (bunch) |
| Total . . | 208 | None | 228 | 13 cases of mutations (8 bunches) |

dominant mutation causing the appearance of beaded wings and a shortening of *L*5, non-lethal in a homozygous condition. Though the identity of this mutation with the known *Bx* mutation is as yet not tested, it is highly probable that they are allelic. The second place is occupied by the recessive sex-linked mutation crossveinless, allelic to the known *cv* mutation (4 cases, one of which was not studied further). Finally, two mutations (broad-dachs and plexoid) appeared once each. The first of them is as yet not localized, the second is an autosomal semidominant.

The above data show that the treatment used in our experiments induces mutations in *Drosophila* and, probably, acts in this respect specifically, giving rise only to a number of definite mutations.

It should be noted that most mutations arose in «bunches» (5 cases of *Bx*, 1 case of *cv*, plexoid, broad-dachs). Seemingly, they arose on an early stage of development. The mutations obtained in the $F_1$ are phenotypically very similar to the specific «morphoses» caused by the immediate action of nucleic acid. Probably, these «morphoses» are in fact somatic mutations of the same genes. In two cases this assumption was directly proved. One male of the *Bx*-type obtained under the influence of nucleic acid when crossed with an attached *X* female gave 36 normal and 8 *Bx* males. Another male of the same origin, having one *cv* wing, gave in a similar cross 12 normal and 24 *cv* males. Both these mutations are easily classifiable, and it is evident that both males were of a mosaic structure.

It is as yet impossible to say whether the same treatment can induce other mutations (i. e. lethals and autosomal recessives); corresponding experiments are already under way. Nevertheless, the results obtained make it highly probable that the sodium salt of thymo-nucleic acid induces in *Drosophila* specific gene mutations. This fact promises to throw a new light on a number of theoretical problems (evolution, gene chemistry), as well as on the practical problem of induction of directed mutations in economically valuable organisms.

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*GENETICS*

# EFFECT OF X-RAYS UPON DIFFERENT LARVAL STAGES OF *DROSOPHILA MELANOGASTER* AND PHAENOCOPY FREQUENCY

By W. I. GRATZIANSKY

*(Communicated by N. I. Vavilov, Member of the Academy, 11. VIII. 1939)*

Since the discovery by Goldschmidt ([4],[5]) of phaenocopies, a whole series of studies were devoted to the mechanism of this remarkable phenomenon ([2],[3],[6],[7],[8]). Among the theoretical problems of evolutionary genetics the one of phaenocopies has also acquired a significant importance([9]). However, even at the present time there are no data of any extensiveness or statistical significance on the relation of the frequency of occurrence of phaenocopies to the age when the influence was applied.

I have undertaken a special study of the relation of the frequency of the roentgenomorphoses to the larval stage at the moment of X-raying.

Material and Technique. The experiments described below were conducted on the larvae of the Bukhara population of *Drosophila melanogaster* which has been bred in the laboratory since 1936. In order to compare ages in each experiment, eggs deposited during a short period of time were obtained from the same fertilized ♀♀ (30.5 ♀♀ per vial in different experiments).

When the desired age was attained, a portion of larvae was taken out of the vials and X-rayed with the dosage of 3000 *r* (50 kV, 4 mA, 1 mm Al, 53′30″); the larvae remaining in the vials served as controls for the registration of the spontaneous proportion of phaenocopies. All the modifications visible under the binocular microscope were recorded; the quantitative comparison of the age differences was conducted on a single modification which is the one most rare in control and most frequent in experiment, viz. «notched wings»(=*KN*—Goldschmidt's effect). The registration and inspection of the flies were conducted on each day's hatching separately in order to estimate the rôle of the duration of development in the frequency of occurrence of phaenocopies.

Three experiments were performed: the larvae irradiated in the experiment No. 1 were 42—48-hour old and 90—96-hour old (counting from the hatching of the larvae). In the second experiment 14—18-hour and 90—94-hour old larvae were irradiated. Experiment No. 3 embraced four age groups: 43—46-hour old, 66—69-hour old, 87—92-hour old and 113—116-hour old larvae (the latter in the state of praepupae).

In the experiment No. 1 the X-rayed material and the control made later development at a temperature of 15—17° C, whereas all the remaining experiments were conducted at 25° C; prior to X-raying the development by all the experimental and control series was made at 25° C. The 90—94-hour old

larvae of the second experiment were collected only from the walls of the vials, i. e. only those ready to pupate were selected; they were variants capable of quicker development (for the significance of this experiment, see below).

The percentages of *KN* for each 24-hour period and for the total of an experimental series were statistically evaluated by means of the mean error of the proportion ($m_q$) and the mean error of the difference ($m_{diff}$).

Results. The data on the relation of the *KN* percentage to age at the moment of X-raying are summarized for the three experiments in Fig. 1, where percentage of flies possessing notches on wings is represented by columns; the bases of the columns represent the maximum difference of ages in a given series; the difference is plotted on the scale of ages expressed in hours of development elapsed from the moment of hatching. Fig. 1 shows that the influence within the second and even the first 24-hour period of larval development

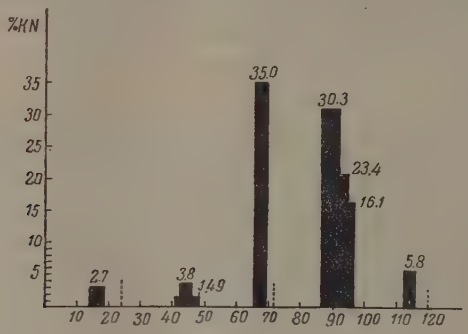


Fig. 1.

causes a perceptible appearance of notches which greatly exceed their spontaneous percentage in non-X-rayed controls (Table 1). The differences between the spontaneous percentages of *KN* and those induced on the 1st or 2nd day of larval development are statistically significant (both in individual experiments and in the case of the minimum difference).

Table 1

| Larval age, hours | In experiment | | | In control | | | diff $\pm$ $m_{diff}$ |
|---|---|---|---|---|---|---|---|
| | % *KN* | $m_q$ | *n* | % *KN* | $m_q$ | *n* | |
| 42—48 . . . | 1.49 | 0.39 | 1491 | 0.2 | 0.14 | 1272 | $1.29 \pm 0.39$ |
| 14—18 . . . | 2.7 | 0.66 | 563 | 0.12 | 0.03 | 1493 | $2.58 \pm 0.67$ |
| 43—46 . . . | 3.8 | 2.19 | 77 | 0.31 | 0.18 | 996 | $3.49 \pm 2.82$ |

Minimum difference — $1.49 - 0.21 = 1.18 \pm 0.42$.

The greatest difference in the experiment No. 3 is insignificant, which is, however, of no importance owing to the small number of the experimental material.

On the other hand, the *KN* percentage induced on the first or second day is much lower than when influence was applied to 3 or 4-day old larvae (Table 2).

It is evident that the «sensitive period» for the production of *KN*-phaenocopies in the larvae of the Bukhara population falls into the 3—4 days of the larval development, as on the 5th day of development the *KN* percentage is significantly decreased and approaches that on the first or the second day of larval life. The drop in the *KN* % within the sensitive period from the maximum at the end of the third day is statistically insignificant ($4.7 \pm 4.2$ during a 24-hour period and $5.9 \pm 2.8$ for the transgressing ages at the end of the 4th period of 24 hours). However, the fact that the notches are, as a rule, more pronounced as a result of an influence applied to the 66—69-hour old larvae as compared to the 96-hour old ones enables one to suggest, that the beginning of the sensitive period is the most effective moment for the production of notches on the wings. Probably, this circumstance is an expression of the very mode of formation of notches, which is the lysis of a rudiment already set and embracing the greater regions, the earlier it has begun ([5],[6],[7]) (Goldschmidt's embryological data for the model *KN*-mutations of the type of the allelomorphs of vestigial).

Table 2

| Larval age, hours | Early larvae | | | Late larvae | | | diff $\pm m_{diff}$ |
|---|---|---|---|---|---|---|---|
| | % *KN* | $m_q$ | *n* | % *KN* | $m_q$ | *n* | |
| 42—48; 90—96 . . | 1.49 | 0.39 | 1491 | 16.1 | 1.8 | 818 | $14.11 \pm 1.8$ |
| 14—18; 90—94 . . | 2.7 | 0.66 | 563 | 23.4 | 1.6 | 715 | $20.7 \pm 1.7$ |
| 43—46; 66—69 . . | 3.8 | 2.19 | 77 | 35.0 | 3.53 | 181 | $31.2 \pm 4.12$ |
| 43—46; 87—92 . . | 3.8 | 2.19 | 77 | 30.3 | 2.20 | 412 | $28.01 \pm 3.14$ |

In order to determine with a greater precision the connexion between the phaenocopy frequency and the degree of its expression with the developmental stage attained by the larvae toward the moment of irradiation, when the influence is applied at the end of the sensitive period, one should consider data on the modification of the *KN* percentage on separate days of hatching of imagoes within the limits of an experimental series embracing one age.

Table 3

| Day of hatching | *n* | % *KN* | *n* | % *KN* | *n* | % *KN* | *n* | % *KN* |
|---|---|---|---|---|---|---|---|---|
| 1 | 27 | 0 | 224 | 14.2 | 27 | 18.5 | 84 | 13.0 |
| 2 | 224 | 0.44 | 155 | 58.0 | 592 | 1.34 | 146 | 1.8 |
| 3 | 269 | 5.20 | 301 | 14.8 | | | 287 | 0.6 |
| 4 | 91 | 32.70 | 105 | 0.9 | 606 | 0.99 | 45 | 0 |
| 5 | 88 | 43.1 | 26 | 0 | 266 | 0.77 | 1 | 0 |
| 6 | 117 | 41.9 | 4 | 0 | 60 | 0 | — | — |
| | 90—96-hour old, non-selected | | 90—94-hour old, selected | | 42—48-hour old, non-selected | | 14—18-hour old, non-selected | |

For this purpose can be used the material obtained from irradiation of 90—96-hour old and 90—94-hour old larvae from the experiments No. 1 and 2, where hatching of flies took place in a relatively short time;

the data of the experiment No. 3 are not suited for this purpose as hatching of flies continued there throughout the 3 days and the flies were not numerous enough.

Table 3 represents the distribution of the *KN* percentages across the days of hatching for the individual experimental series.

Differences in the tempo of development occurring in the population are, probably, further increased under the action of X-rays; besides, in the experimental population, which has not been selected for synchronous development, the *KN* percentage showed a very pronounced increase toward the last days of hatching. Among the 90—96-hour old larvae (experiment No. 1) it is thus the individuals the most retarded in development which respond to the treatment by showing notches in a greater part of cases, i. e. the law of decrease of the percentage along with the decrease in the duration of completion of larval development from irradiation to hatching (at the end of the sensitive period) finds also its confirmation. In the second experiment (see technique) only those individuals were irradiated which showed enhanced tempo of development at the age of 90—94 hours; distribution of the *KN* percentages across the days of hatching was greatly modified in this case, the maximum (58% of *KN*) falling on the second day of hatching, and then follows a drop to 0% on the 5th and 6th day of hatching.

This result appears to be of great importance; it proves that late hatching of flies bearing notches on their wings depends on a predisposition of individuals which have been already delayed in their development, but not on delaying influence of the phaenocopy; comparison between the series of the 1st or 2nd experiments of equal age demonstrates the possibility to modify both the *KN* percentage and the distribution of the frequency across the days of hatching through selection of variants for the length of larval development.

The rate of development of different individuals within the population undoubtedly plays some rôle in the determination of the predisposition to produce the *KN*-phaenocopies. At the present time the nature of this connexion is not clear, yet the very fact deserves serious attention, as it is evidence that the matter is not limited to an one-sided effect of the morphose upon the tempo of the subsequent development of the individual.

In concluding one should point to the distribution of the *KN* percentage across days of hatching after irradiation of two and one-day old larvae. Table 3 shows that, when influence is applied at these ages, the *KN* percentage appears to be in a quite different relation to the rate of development of the variants than in the case of treatment of the 4-day old larvae. It is probably because there is a different kind of influence when the treatment is applied prior to or after the sensitive period. In supposing that *KN*-phaenocopies arise owing to an after-effect of X-rays, when one or two-day old larvae are irradiated, I am starting from the following theses. First, the rudiment of the wing is evidently not yet differentiated at these ages and the treatment may bring about its formation only in an indirect way, through cyto-physiological «traces» which are the after-effects of X-raying. Secondly, the most rapidly developing variants when treatment is applied to them prior to the sensitive period most strongly react to the treatment; conversely, the more retarded in development are the 1 or 2-day old larvae, the less is the *KN* percentage (the drop toward the end of hatching).

The available data may be best interpreted in the sense of the «after-effect of the X-rays». The shorter is the period which remains to the irradiated individuals from the moment of X-raying to the beginning of the sensitive period of the phaenocopy in question, the more probable it is that

the «trace-effect» will preserve its efficiency and will be able to cause the morphose without any general developmental disturbances fatal to the larva.

The degree of expression of the phaenocopies at different days of hatching of the flies irradiated prior to the sensitive period is in accord with this statement.

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*MICROBIOLOGY*

# CYTOLOGY, KARYOLOGY AND CYCLE OF DEVELOPMENT OF NEW MICROBES—*CARYOPHANON LATUM* and *CARYOPHANON TENUE* MIHI

By M. A. PESHKOFF

*(Communicated by N. I. Vavilov, Member of the Academy, 11. VII. 1939)*

In my preceding papers on the structure and cycle of development of *Achromobacter Epsteinii* I arrived at the conclusion that many microbes possess the faculty of forming polyenergid stages of growth. The latter are much larger than the monoenergid forms (usually rods 1—2μ long and 0.5—1 μ wide) and vary greatly both in shape and size, the largest reaching 50—80 μ in length and 3—5—20 μ in width. These forms are viable and by means of multiplying by transversal fission, as well as by splitting off of terminal buds they produce again monoenergid bacillary microbes. The nuclei of the monoenergid bacillary forms are usually invisible; those of the giant individuals are present in the form of chromatin spirals or skeins and divide amitotically. These chromatin spirals and skeins are polyenergid structures. Since my knowledge of the polyenergid character of the giant forms of *Achromobacter Epsteinii* was based only on a hypothesis, it was desirable to find in nature some unknown microbe which would provide support heretofore missing for the hypothesis of the mono-polyenergid cycle of development of some schizomycetes.

Such a microbe was found by me in 1937 when I isolated from cow manure a giant microorganism which I named *Caryophanon latum*. A year later I ran across a similar though somewhat smaller microorganism, which I called *Caryophanon tenue*.

The first microbe, *Caryophanon latum*, possesses a cylindrical body which is slightly curved and sometimes takes on the shape of an extended spiral (Fig. 1). The width of the individuals is 3.1 μ, while their length reaches 15—20 μ. The ends of the rods are rounded. The individuals are mobile and swim energetically owing to the movement of a multitude of peritrichate flagella (Fig. 2, 4).

*Caryophanon tenue* is very much like the first microbe except that its body is narrower than that of *Caryophanon latum* and never exceeds 1.5 μ. When live cultures of both microbes are examined under a microscope, it is plainly seen that their protoplast consist of alternating light and dark segments. The light segments are often doubled and their diameter is somewhat shorter than that of the individual's body. Brown's movement of small drops of various inclusions was observed more than once in the dark segments.

Contrary to this the inclusion drops seen in the narrower light segments were always immobile. When examined in dark ground illumination, the light segments appear optically empty; while shining mobile drops of various inclusions were observed in the regions corresponding to dark segments (Fig. 2). These data show that the substance of the light segments is more solid, while that of the dark regions is often in a liquid state.

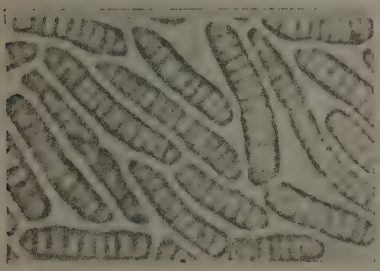

Fig. 1.

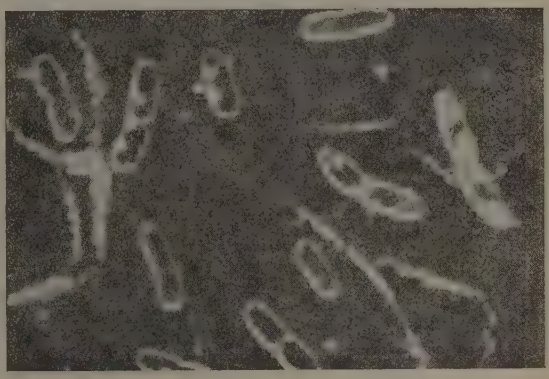

Fig. 2.

Fig. 3.

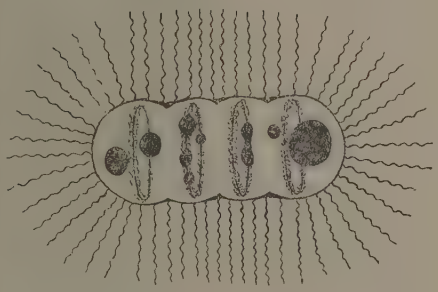

Fig. 4.

When stained after Giemsa or treated according to Feulgen, the substance of the light segments gave a reaction typical of chromatin. The behaviour of the light segments rich in chromatin was studied during the division of the individual with the help of the serial photomicrograph method. A dividing individual was taken under observation (Fig. 3, *I*).

The number of the light segments of the individual is equal to 17. The organism begins to divide; the strangulation line is seen to appear between the fifth and the sixth light segment. Photomicrograph *II* shows that the individual has grown much and undergone a second division. In the region of the division the light segment No. 5 has split longitudinally. The light segment No. 9 has undergone a similar longitudinal splitting. Photomicrograph *III* shows that the light segments No. 3, 4 and 17 have also split longitudinally, while photomicrograph *IV* shows that a similar process has invol-

ved the light segments Nos. 1, 7, 8, 11 and 13. The fact that new divisions of the individual's body occur only between the two pairs of recently split and therefore double light segments Nos. 3/3, 4/4 and 7/7, 8/8 is of great importance. Thus, the light segments which consist of chromatin multiply by longitudinal fission; their division precedes that of the individual. Consequently, they behave like monochromosome nuclei.

The results of a thorough cytological investigation of *Caryophanon* follow. The individuals possess a rather thick membrane (Fig. 4) (about 0.2 μ), solid and little permeable. The membrane is reinforced from within by circular hoops which divide the cavity of the individual's body into a series of open compartments. Numerous peritrichate flagella, which must originate from the protoplast, cover the individual's body. The protoplasm is liquid but viscous, and often contains volutin shown in the scheme in the form of large black drops which sometimes adhere to the nuclei.

Each compartment contains at least one nucleus. The nuclei are rich in chromatin and have the shape of hoops.

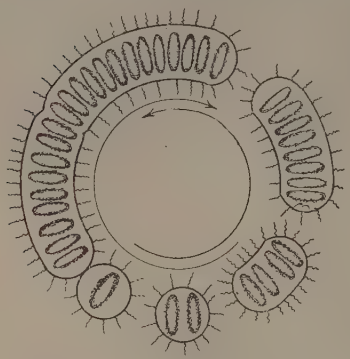

Fig. 5.

The inner structure of the new microbes has much in common with that of some blue-green algae (oscillaria, oscillospira), except that:

1. The trichomes of oscillaria are partitioned and consist of many separate cells each containing a central body.

2. The blue-green algae are either immobile or crawl upon the substratum like some green algae by means of fountains of ejected mucous substance and never possess flagella, even in the embryonic states of development.

In spite of many common features in the organization of the oscillaria and the new microbes, the latter differ in the following points from the blue-green algae:

1. The individuals of the new microbes are not divided into separate cells and represent closed tubes containing a varying number of nuclei and a common protoplasm. They are devoid of pigments.

2. The organisms are motive exclusively by means of numerous peritrichate flagella. As the new microbes possess nuclei which are always visible and are their most outstanding feature, the name *Caryophanon* was thought of as the most appropriate one. Evidently, these microbes are representatives of a new genus *Caryophanon* of a new family *Caryophanaceae* of a new order *Caryophanales* of the class of *Schizomycetes*.

*Caryophanon latum* et *tenue* are found in 20—30% of samples of fresh cow manure. Isolation in pure culture requires some patience. Once obtained, the strains are cultivated on sterile manure extract containing 2% of agar, pH =7.8. Aerobic, do not grow on ordinary laboratory media. Growth in the form of round colonies reaching 1—2 mm in diameter.

Subject to distinct *S—R* variation. The individuals of *Caryophanon latum* et *tenue* can be mononucleated (monoenergid), coccoids and polynucleated (polyenergid) bacilli. Both microorganisms, while growing on nutritive media, undergo a peculiar cycle of development shown in Fig. 5. A polyenergid individual containing 22 nuclei is seen to the left. It divides transversally; besides, a terminal monoenergid bud splits off of one of its ends. Such a monoenergid bud develops in future into a 2—4 or 8-nucleated polyenergid individual.

If the tempo of division of the individual's body drops and becomes slower than that of the nuclei while growth proceeds, this will result again in the formation of a long polyenergid individual. Coincidence of the tempo of division of the nuclei and individual's body will lead to the formation of short organisms with 4—2 or 1 nucleus. The ability of the cycle of development to follow any of the two directions is shown in the scheme by two intersecting arrows.

Thus, the finding of *Caryophanon* in nature has made demonstrable the author's hypothesis of the mono-polyenergid cycle stages of some schizomycetes. In virtue of the facts stated above, it is no longer a hypothesis, but already a theory.

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*HISTOLOGY*

# INFLUENCE OF «VITAL» STAINS ON THE CARBOHYDRATE METABOLISM OF IN VITRO GROWING TISSUE

By A. V. RUMJANTZEV

*(Communicated by I. I. Schmalhausen, Member of the Academy, 9. VIII. 1939)*

Intravital staining or, to be more precise, deposition of stains in tissue growing in vitro, has been studied in considerable detail. It can be regarded as established that both acid and basic stains, penetrating into the cell, provoke the formation of vacuoles in its protoplasm; these vacuoles become the centers of further deposition of the stain ([1–3]). Experiments on prolonged staining show that there exists a limit for the accumulation of the stain, beyond which it is no more possible either to obtain the formation of fresh vacuoles or to increase the deposition of the stain in those already formed ([4,5]). Kedrovsky ([5]) was able to produce incontrovertible evidence that in the course of in vivo staining the stain extracts acid colloids from the protoplasm and that these colloids unite with the stain. Cells overloaded with stain are capable of proliferation ([1–3]). Judging by the structure of the cytoplasm and nucleus, such cells do not show symptoms of degeneration and they may live for some time in the cultures.

A number of questions arise, however, which up till now have been but little touched upon in regard to in vitro growing tissue. First of all, is it possible to consider stain overloaded cells «normal», and what is the later fate of the stain deposited in the protoplasm?

To answer these questions we decided: 1) to investigate the metabolism of stained cultures, and 2) to follow up the fate of stained granules in subcultures. In the present study the results of our investigation of the carbohydrate metabolism of cultures stained to the limit are described.

Material and Technique. Heart tissue of 8-day-old chicken embryo. Medium: 6 parts of plasma+2 parts of stain in physiological saline +2 parts of glucose in saline. Concentration of glucose 0.15%. Stains tested: neutral red (N. R.), methylene blue (M. B.), pyrol blue (P. B.). The stains were added in such concentrations, that the final dilution in the culture medium was for M. B.—1:10000 and 1:20000, for N. R.—1:25000 and 1:50000, and for P. B.—1:5000. For testing the carbohydrate metabolism of growing tissue we determined the quantity of sugar in the medium of 48-hour cultures; the determinations were made according to the method of Haagedorn-Jensen*. For these determinations we took several cultures, since individual

* This method is not perfectly precise.

cultures show quite considerable variations in regard to the consumption of sugar from the surrounding medium (from 30 to 70%).

Fig. 1 shows simultaneously the growth and the consumption of sugar, the figures of the control being assumed to equalize 100%.

Observations on growth have shown that the cultures produced excellent growth, and the sizes of the zones after 48 hours were perfectly similar. The same can be said of sugar consumption; it was practically the same in both tests and differed but little from that of the controls. The slight decrease of consumption (by 7%) in the exp. I and its slight increase in the exp. II lie within the limits of error and therefore cannot be considered as the effect of staining.

Experiments with N. R.

| Series I | Medium | Number of cultures | Weight of cultures | Quantity of sugar detected, mg % | Sugar consumption in comparison with medium alone, % | Sugar consumption in comparison with control, %* |
|---|---|---|---|---|---|---|
| Control | Plasma + glucose + embryonal juice | 4 | 101 | 78 | 53 | |
| | | 6 | 203 | 61 | 63 | |
| | Medium alone (without tissue bit) | 6 | 276 | 165 | | |
| Experiment | Same as in control + N.R. (total conc. 1 : 50000) | 6 | 162 | 71 | 51 | decrease — 7 |
| | | 6 | 171 | 62 | 57 | |
| | Medium alone (without tissue bit) | 6 | 215 | 148 | | |
| | | 4 | 103 | 145 | | |
| Series II | | | | | | |
| Control | Plasma + glucose + + embryonal juice | 9 | 200 | 118 | 39 | |
| | Same, but without tissue | 6 | 237 | 194 | | |
| Experiment | Plasma + glucose + + embr. extract + + N.R. (total conc. 1 : 25000) | 9 | 195 | 142 | 42 | increase + 7% |
| | Same, but without tissue | 9 | 184 | 248 | | |

Fig. 2 shows that growth in general was not bad. However, both in exp. I and in exp. II growth was less profuse than in the controls, and the depression of growth in cultures with a larger concentration of the stain (1.10000) exceeded that of the cultures with the lesser stain concentration (45 and 33% resp.). At the same time the consumption of sugar was higher than in the control, by 65% in the exp. I and only by 24% in exp. II.

If we consider the inhibition of growth, i. e. the decreased amount of tissue accompanied by an increased sugar consumption, the conclusion seems

* In calculating the consumption ratio we took the mean of the values found.

Experiments with M. B.

| Series | Medium | Number of cultures | Weight of cultures | Quantity of sugar detected | Consumption of sugar, mg % | Consumption of sugar, % of control |
|---|---|---|---|---|---|---|
| | Plasma + glucose + + embr. extract . | 6 | 210 | 237 | 29 | |
| | Same, but without tissue . . . . . | 6 | 200 | 321 | | |
| Exp. I . . . | Same + M. B. (total conc. 1 : 10000) | 6<br>6 | 240<br>157 | 106<br>73 | 39<br>58 | + 65 |
| | Same, but without tissue . . . . . | 6 | 185 | 174 | | |
| Exp. II . . . | Same + M. B. (total conc. 1 : 20000) . . | 6<br>6 | 222<br>220 | 210<br>217 | 37<br>35 | + 24 |
| | Same, but without tissue . . . . . | 6 | 196 | 333 | | |

justified, that M. B. stimulates the consumption of sugar by in vitro growing tissue and simultaneously inhibits cell proliferation.

Experiments with P. B. (sugar determined after 48 hours of growth)

| Series | Medium | Number of cultures | Weight of cultures | Quantity of sugar detected, mg % | Sugar consumption as compared with medium alone, % |
|---|---|---|---|---|---|
| I . . . . . | Plasma + glucose + embr. extract (P. B. — 1:500) . | 10 | 251 | 104 | 65 |
| | Same, but witbout the bit of tissue (medium alone) | 6 | 185 | 298 | |
| II . . . . . | Plasma + glucose + P. B.+ + embr. extract (P. B.— — 1 : 500) . . . . . | 5 | 188 | 291 | |
| | Medium alone . . . . . | 5 | 231 | 245 | 47 |

The cultures grew excellently and there was no difference whatever between test and control cultures; the absolute area increase in the control equalized 37.04, in the exp.—37; sugar consumption was in the control and in exp. I—60%, in exp. II—54%, i. e. there was no difference in the consumption of sugar either. The loading of the cells with P. B. affected neither growth, nor metabolism.

Conclusions. Myoblasts of the heart of chicken embryos implanted into a stain-containing medium are overloaded with the stain which accumulates in their protoplasm. The greatest quantity of stained granules is observed in cultures with N. R., in which almost the entire protoplasm is filled with stained granules; somewhat less ist their number in M. B., and it is the least in P. B. The cells loaded with the stain proliferate, form a good zone of growth, and a certain depression of growth is observed only in the case of M. B.: in those of N. R. and P. B. growth practically did not differ from the controls (Fig. 1). Determinations of sugar consumption show that M. B. stimulates it sowemhat, while N. R. and P. B. leave it entirely unaffected.

On the ground of the results obtained one can assume, that the loading of the cell «vacuome» with stain and the increased formation of a new «crinome» do not lead to the alteration of its carbohydrate metabolism. It fol-

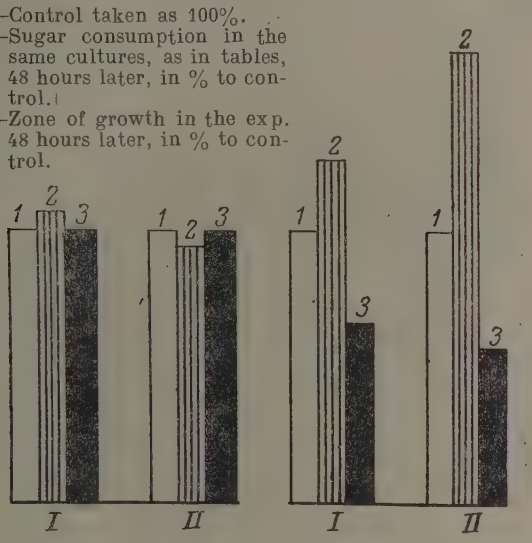


Fig. 1. Experiments with N. R. Fig. 2. Experiments with M. B.

lows that the cell «vacuome» does not participate in the decomposition of sugar and accordingly the hypothesis concerning its significance as of a ferment depôt is not confirmed by our experiments. Apparently, the process of the decomposition of sugar takes place either on the surface or throughout the entire protoplasm untouched by the stain. If so, it is impossible to regard the process of the deposition of stain as a «model» permitting to judge of the phenomena of protection arising in the protoplasmic system, when such substances which cannot be involved into its metabolism penetrate into it.

The stimulation of sugar consumption by M. B. and the absence of such stimulation in the case of N. R. and P. B., established by us, agree perfectly with the available literary data. Sugar is the chief energetic source. If the consumption of $O_2$ is increased, the tissue evidently utilizes more sugar than normally; consequently, by the sugar consumption one can judge of the dimensions of respiration and vice versa. Therefore we are greatly interested in the data on the respiration of tissue in the presence of stains. It can be considered as established that M. B. raises the consumption of $O_2$ by the unfertilized eggs of sea-urchins and starfishes, by the red blood cells and by some

tissues of mammals ([6-10]), while N. R. and e. g. trypan-blue are perfectly indifferent ([7,11]) and do not affect carbohydrate metabolism. According to our results, carbohydrate metabolism is raised only in the presence of M. B. in spite of the simultaneous depression of growth. If this be so, then the catalytic action of stain does not depend on its penetration into the cell, since in our tests the cells were loaded with stains to the limit. Without dwelling on the mechanism of the effect itself, we regard as the most probable the supposition of Barron and Hoffman that only those stains, which are able to be oxidized and reduced reversibly, can be active as catalyzers, but we are inclined to deny the high significance of permeability.

All the stains employed by us in these experiments penetrated readily into the cells, yet an effect could be detected only in the case of M. B. Observations on the alterations in the deposited stains during prolonged cultivation of the tissue show that N. R. discolorates and dissappears earliest of all, while M. B. granules are present also in subcultures. While the process of the disappearance of stained granules is pretty similar for N. R. and P. B., in the case of M. B. it shows some differences, and, speaking generally, M. B. keeps on in subcultures for a longer time than either N. R. or P. B. Since strongly stained cultures could be readily transferred, and after the 3rd transfer for N. R. and the 4th for P. B. the cultures grew normally, showing no traces of the stain in the cells, one can conclude that «vital» stains do not affect the chief vital structures of the cells, and therefore the stain-loaded cells, in spite of the separation of some acid proteins which has taken place ([5]), can be regarded as perfectly normal.

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*ANIMAL PHYSIOLOGY*

# COMPARATIVE ANALYSIS OF CONSTITUTION OF DOMESTIC AND WILD SHEEP

By S. N. BOGOLYUBSKY

*(Communicated by I. I. Schmalhausen, Member of the Academy, 1. VIII. 1939)*

The comparative analysis of the constitution of wild animals raised on farms offered me the opportunity of providing supplementary systematized data characterizing some species of these animals by their build. We have applied the same methods in analyzing the constitution of some breeds of domestic sheep, groups of half-breeds, wild rams, and also crosses of the domestic and wild sheep. The difference in the constitution of the various domestic breeds is less distinct and requires further study and a microscopic analysis of the structure of the organs, which so far has not been done because of the difficulties in the way of such a study. On the one hand, the material under investigation has to be taken special care of, and on the other, the conditions prevailing at the slaughter-houses do not answer the requirements of analysis of the constitution of the animals. In big slaughter-houses such analysis is practically impossible because of the conveyer method of treating the carcasses and because the animals slaughtered are of a mixed kind. For this reason we had to use casual material, either defective or dead animals, making thereby allowance for pathological changes. Notwithstanding all these difficulties we succeeded in analyzing some healthy and rather homogeneous groups in numbers allowing biometric study. The non-homogeneous, odd material was considered as supplementary against the background of more homogeneous populations. The latter consisted of 30 Precoce ewes from pedigree farm № 1, 32 Merino ewes (Rambouillet) from Frunze State Farm, and 50 young wethers (from 16 to 17 months of age), from Ascania Nova, some of them of the Chuntuk breed and the others, half-breeds. In addition 15 Tsigai ewes were investigated. The Precoce and Merino ewes were impregnated in order to obtain embryos from them.

The percentages given in the tables below show the respective proportions of weight of a particular organ to total live weight. The bulk difference between the Precoces and the Merinos (Rambouillet) is obvious from the average weight of their omenta, both great omentum and lesser omentum.

The weight of the omenta is as follows:

In the Precoces (30 in number): $M \pm m = 1.07 \pm 0.065$ kg
» » Merinos (32 in number): $M \pm m = 0.331 \pm 0.02$ kg
» » Tsigais (15 in number): $M = 0.408$ kg
» » wethers (50 in number): $M \pm m = 0.522 \pm 0.03$ kg

The Precoces had the greatest live weight, and were followed by the Merinos and the Tsigais. Thus, the Precoces are the largest of all, showing better meat qualities, as may be seen from the weight of their omenta. The following table shows the proportion of the basic organs to the total live weight in the main groups.

| | Precoces ($n$=30) | Tsigai ($n$ = 15) | Merinos ($n$ = 32) |
|---|---|---|---|
| Live weight, kg | 61.2 ± 1.06 | 42.8 | 46.5 ± 0.36 |
| Heart, ‰ | 3.95 | 4.5 | 4.66 ± 0.08 |
| Omenta, ‰ | 17.42 ± 1.09 | 9.52 | 7.79 ± 0.50 |
| Lungs, ‰ | 10.43 ± 0.30 | 15.44 | 16.4 ± 0.18 |
| Liver, ‰ | 20.46 ± 0.47 | 16.10 | 18.69 ± 0.21 |
| Spleen, ‰ | 2.99 ± 0.1 | 1.79 | 1.89 ± 0.04 |
| Right kidney, ‰ | 1.68 ± 0.03 | 1.87 | 1.49 ± 0.036 |
| Blood, ‰ | 47.75 ± 0.09 | 45.2 | 30.2 ± 1.1 (?) |
| Hide, ‰ | 95.8 ± 1.5 | 107.9 | 124.6 ± 0.27 |
| Eye, ‰ | 0.30 ± 0.009 | 0.44 | — |
| Brain, ‰ | 1.96 ± 0.038 | — | — |
| Right thyroid gland, ‰ | 0.026 ± 0.002 | 0.025 | — |
| Right suprarenal capsule, ‰ | 0.038 ± 0.002 | 0.07 | — |
| Small intestine, ‰ | 14.98 ± 0.39 | — | 15.05 ± 0.25 |
| Large intestine, ‰ | 10.87 ± 0.32 | — | 12.53 ± 0.23 |
| Empty stomach, ‰ to live weight | 34.18 ± 0.67 | 37.7 | 37.7 ± 0.46 |
| Rumen, % in stomach weight | 56.12 ± 0.63 | 59.3 | 50.0 ± 0.63 |
| Reticulum, % in st. wh. | 11.7 ± 0.28 | 10.84 | 14.4 ± 0.025 |
| Omasum, % in st. wh. | 10.2 ± 0.31 | 12.46 | 15.4 ± 1.27 |
| Abomasum, % in st. wh. | 22.0 ± 0.44 | 15.4 | 20.2 ± 0.24 |
| Length of small intestine, m | 30.2 ± 0.44 | 29 | 31.05 ± 0.41 |
| Coefficient of length of small intestine to oblique length | 42.34 ± 0.58 | 48.69 | — |
| Length of large intestine, m | 6.64 ± 0.20 | 6.03 | 5.93 ± 0.09 |
| Length of caecum, m | 0.41 | 0.44 | 0.35 |

The Merinos and the Tsigais were of equal bulk, while the Precoces were plumper. It was therefore only natural to expect that the proportional weight of the various organs would prove lower in the latter.

However, the proportional weight of the omenta, spleen and blood was found to be much higher in the Precoces than in the Merinos and Tsigais. This was probably because these organs were correlated physiologically to the animal's bulk. The proportional weight of the various organs in not particularly fat wethers points to the same. Thus, taking the average weight indices of young Chuntuk and Hampshire-Chuntuk wethers, we find that their heart is small (3.9‰) and so are also the lungs (7.6‰) and the kidney (1.43‰). The spleen is comparatively small (1.23‰), the eye is similar in weight (0.39‰), the brain (1.75‰) and the suprarenal capsule (0.032‰) are smaller, while the thyroid gland is somewhat larger (0.031‰).

The Precoces and the Tsigais show a greater weight of the kidneys and a greater weight and length of intestine as compared with the Merinos. The Tsigais show a greater weight of the eye as compared with the Precoces and their caecum is longer. The Precoces come first in regard to the development of the abomasum and are followed by the Merinos and then by the Tsigais. In this respect the Precoces, according to our measurements, come near to the Hampshires, and according to Hammond, to the Suffolks. The rumen, however variable, is on the average more developed in the Precoces than

in the Merinos, while the intestine of the Merinos is longer than that of the Precoces.

The difference in the constitution of the domestic breeds is much more salient when we compare them with the wild breeds, as well as with crosses of the latter and the domestic sheep. In this respect the data relating to *Ovis musimon* (5 heads) in Ascania Nova, *Ovis polii karelini* (17 heads) and *Ovis vignei* (1 head), collected by myself and by Denisov and Bairov, are significant.

The material collected by me refers to the first generation of crosses between *Ovis polii* and the fat-tailed (kurdyuk) breed, as well as between *Ovis vignei* and sheep of no particular breed. Of the six hybrids three (two wethers and one ewe) were taken from the herd of the Institute of Genetics at the state farm near Issyk-kul and three (two rams and one ewe) from Moscow Zoo.

The live weight of adult males of the *Ovis polii karelini* varied between 96 and 171 kg, while that of the females between 65 and 75.4 kg. The proportional weight of the heart is greater in wild rams than in any of the domestic breeds. Only in a few of the Ascania Nova moufflons does the proportional weight of the heart approach that of the domestic breeds. Excluding these few moufflons which have obviously changed by way of occasional crosses with the domestic sheep or owing to their semidomestic life, we note the absence of any transgression in the proportional weight of the heart in the wild rams as compared with the domestic rams. In hybrids the proportional weight approaches that of the domestic sheep. Only in two bulky rams did the proportional weight show an approach to that of the wild breed—6.2‰. The diameter of the trachea, which in domestic sheep never exceeds 2 cm, is very large in the wild rams and reaches 3 cm. The proportional weight of the lungs of wild sheep varies between 18 and 34‰, while the lungs of healthy domestic sheep never exceed 17‰.

The proportional weight of the lungs of the hybrids from the Zoological Garden was from 6.1 to 10.2‰, while that of the hybrids from the mountains varied between 14.7 and 19.2‰. Here we clearly see the effect of station on heredity, we see that herd life in the mountains, under normal conditions of movement, is conducive to greater development of the lungs. On the other hand, the lungs of the hybrids from the Zoo showed no signs of hereditary transmission of their wild parents. The kidneys of the wild rams, calculated on the basis of the data for the right kidney only, showed considerable variations. Of the 21 wild rams investigated, most of them *Ovis polii karelini*, and moufflons from Ascania Nova 12 showed a proportional weight of the kidneys similar to that of domestic sheep, and varying within the range of data for the domestic sheep; 9 had kidneys of a larger mass with their respective weights lying beyond the upper limit for the domestic sheep. The mean weight of their kidneys was 2.09%, i. e. it exceeded the $M$ of any of the domestic breeds studied. Judging by Denisov's materials, the *Capra sibirica* shows a high proportional weight of the kidneys. The $F_1$ hybrids from a cross between the fat-tailed sheep and the wild *Ovis polii karelini* showed no increase in proportional weight of kidneys as compared with the domestic sheep.

In regard to the brain our material is rather small. The brain of a female *Ovis polii karelini*, with a body weight of 44 kg, weighed 200 g or 4.83‰. The brain of an *Ovis musimon* weighed 128 g showing a proportional weight of 4.7‰. Comparing these indices with the material on the Precoce ewes and the wethers of various breeds, we find that the proportional weights of wild sheep are twice the $M$ of the domestic sheep, being always far beyond the variation range of the latter. The proportional weights of the

$F_1$ hybrids from the Zoo were 2.65 and 4.14‰, one being near to that of the wild sheep and the other somewhat exceeding the range of the domestic sheep. The proportional weight of the eye of the *Ovis polii karelini* was 0. 69 and 0.81‰, or nearly double the proportional weight of the eye of the domestic sheep. The moufflons from Ascania Nova showed the following proportions: 0.71, 0.50 and 0.34‰. Only the first index equals that of the wild sheep. The proportional weight of the eye in all the hybrids was similar to that in the domestic sheep.

As to the suprarenal capsule and thyroid gland, their weight in two sheep of the *Ovis polii* and *Ovis vignei* was almost double that of the domestic sheep and of the hybrids. The moufflons showed the same picture. The proportional weight of the empty stomach of the wild rams (*Ovis polii karelini*) and the moufflon was 26.0 and 27.8‰, or less than that of the various breeds of domestic sheep.

The abomasum of the *Ovis polii karelini*, in proportion to the total body weight and to the weight of the whole stomach, is smaller than that of the domestic sheep. According to my observations, the length of the small intestine of the wild rams of the *Ovis polii karelini* varied between 18.3 and 21.5 m, which means that the oblique length varies between 21.5 and 28.6 m. According to Bairov's observations, the length of the small intestine of the *Ovis polii karelini* varied between 24.3 and 27.5 m, that is, it fell short of the average length of that of the domestic sheep. We can affirm with certainty that on the average the intestine of the *Ovis polii karelini* is about three quarters that of the Precoce or the Merino. But in some of the *Ovis polii* the small intestine was longer than that of the domestic sheep. However, considering the large size of the *Ovis polii*, judging by our data, there is really no transgression in the length of the small intestine. The small intestine of the hybrids from the Zoo was shorter than the minus-variants in domestic sheep, while the small intestine of the mountain breeds was longer, equalling in length that of the domestic sheep.

## Conclusions

1. The comparison made between the size and weight of the various organs of wild sheep (*Ovis polii*, *Ovis vignei*, *Ovis musimon*. etc.) and of the domestic sheep has shown that the wild sheep have a more developed brain, eye, heart, lungs, kidneys and apparently also suprarenal capsule and thyroid gland. However, as far as the digestive organs are concerned, the intestine of the wild sheep is on the average only three quarters that of the domestic and the proportion of the compartments of the stomach seems to be somewhat different.

2. The $F_1$ crosses between wild rams and domestic sheep have shown a lack of homogeneity in regard to the previously mentioned characters. Thus, in weight, the lungs of the animals from the Zoo approximated those of the domestic sheep, while the lungs of the mountain sheep approximated those of the wild rams. In regard to the weight of the brain, hereditary transmission varies. The weight of the eye in hybrids is the same as in domestic sheep. The weight of the rumen in mountain hybrids is greater than that in hybrids from the Zoo. With the abomasum it is the other way about.

3. In regard to constitution our study of the populations of Precoce, Merino and Tsigai ewes has not shown any clearly defined differences between these breeds. However, the variation curves and the mean figures tend to show that the Merinos and the Tsigais have a greater weight of the lungs and a smaller weight of the liver and spleen; Precoces, a somewhat

shorter small intestine, a lighter stomach and a more developed abomasum. These differences are to a certain extent related to the fact that the animals of the latter breed (Precoces) were bulkiest.

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ZOOLOGY

# ZOOGEOGRAPHIC CHARACTERISTIC OF *ASELLIDAE* OF LAKE BAIKAL

By J. A. BIRSTEIN

*(Communicated by S. A. Zernov, Member of the Academy, 24. VI. 1939)*

For the final solution of the problem of origin of the Lake Baikal fauna it is necessary to make a detailed zoogeographic analysis of the composition of animal groups populating this lake. Some of the groups have not yet been subjected to such analysis, in spite of the fact that the Baikal may be regarded faunistically as one of the most thoroughly investigated water basins in the world. I shall endeavour to fill partly this gap by analyzing the relationships of the Baikal *Asellidae*—a group which attracts more and more the attention of zoogeographers of to-day.

I am indebted to Prof. G. J. Vereschagin and M. M. Kozhov for the privilege of working on the rich material on asellids collected by the Baikal Lymnological Station of the Academy of Sciences of the USSR and by the Irkutsk State University. A complete account of the results of the taxonomic treatment of the above-mentioned material has been included in the monograph «Fresh-Water *Asellota* of the USSR» (USSR Fauna, v. VII, ed. 5), now about to be published. In the present paper I am giving only such principal conclusions as are of interest from a zoogeographic viewpoint.

The first information on Baikal asellids was published by Grube who had described in 1872 *Asellus baicalensis* ([7]). 12 years later the same species under the same name was redescribed by Dybowski; the latter had no knowledge of Grube's work. In addition to that, Dybowski described from the Angara river a closely related species—*A. angarensis* ([5]). In 1922 Alpatov disclosed the two mentioned species in the Chivyrkuisk bay of Baikal, where *A. angarensis* proved to be more abundant than *A. baicalensis*. On comparing the Baikal *Asellidae* to those of North America, Alpatov found them to have a great deal in common and thought it possible to unite the two under one subgenus ([1]).

In 1924 Semenkevich published preliminary results of the treatment of asellids collected by Korotnev's expedition. To the two species already known he added 3 new ones—*A. korotnewi*, *A. minutus* and *A. dybowskii*, however, they were insufficiently described and not figured by him ([11]).

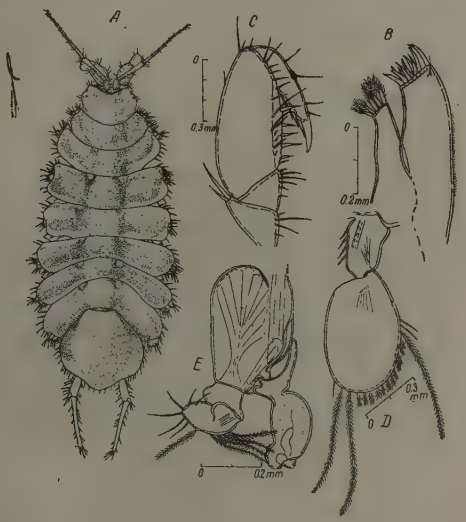
In 1932 Stammer revised chiefly the European *Asellus* species. He reinvestigated the materials of Grube using them, together with the data of Dybowsky and Semenkevich, as a basis for the differentiation of the Baikal asellids into a separate endemic subgenus *Baicaloasellus* ([12]). However,

the treatment of the material I have had at my disposal has shown that Stammer's system is in need of certain correctives.

By way of supplementing Stammer's diagnosis, one may characterize the subgenus *Baicaloasellus* as follows:

Inner lobe of the first maxilla bearing 5 setae. Propod of 1st pereiopod ♂ without any process, broad, more than one half as broad as long. Endopod of 2nd pleopod ♂ without outgrowth in the basal region; its tip extended in the shape of a beak, chitinized, lateral lobe wanting. Second pleopods ♀, drawn out longitudinally, trapezoidiform, broadening toward the distal end and not extending over each other. Epimera well developed.

These characters are common to all the asellids of Baikal, except *A. dybowskii*. As to the last-mentioned species, there is no ground for assigning it to the subgenus *Baicaloasellus*, owing to the peculiar structure of the




*Asellus (Mesoasellus) dybowskii* Sem. ♂: *A*—general aspect (II antennae broken off); *B*—first maxilla; *C*—end of 1st pereiopod; *D*—1st pleopod; *E*—2nd pleopod.

second pleopod ♂—a most significant feature in the taxonomy of *Asellidae*. The end of the endopod of the second pleopod in *A. dybowskii* is not produced into a beak-like structure and exhibits a much more complicated arrangement than in representatives of the subgenus *Baicaloasellus*. At the base the endopod bears a long outgrowth directed inward, and the whole second pleopod ♂ *A. dybowskii* looks very much like the second pleopod ♂ in the species of subgenus *Asellus* sensu stricto [*A. aquaticus* (L.), *A. monticola* Birst., *A. hilgendorfi* Bov.]. However, some characters speak against the inclusion of *A. dybowskii* in the subgenus *Asellus* s. str. Thus, for instance, the Baikal species displays 5 (and not 4) setae on the inner lobe of the first maxilla and the propod of first pereiopod ♂ is here an entirely different structure.

In estimating the taxonomic value of all these characters, I think it necessary to isolate *A. dybowskii* into a new subgenus, fit to rank among the subgenera already known, such as *Asellus* s. str., *Proasellus* Dudich, *Conasellus* Stammer and *Baicaloasellus* Stammer. This new subgenus may be characterized as:

## Subgenus *Mesoasellus* n. subgen.

Inner lobe of first maxilla with 5 setae. Propod of first pereiopod ♂ elongate, being more than twice as long as broad; the distal margin destitute of outgrowths. The basal part of endopod of second pleopod ♂ bears an outgrowth directed inward (like in subgenus *Asellus* s. str.). Second pleopods ♀ not extending over each other, triangular. Uropods elongate, in ♂ exceeding in length the pleotelson, with exopods greatly reduced. Epimera feebly developed, though visible in dorsal view.

The question arises as to how far apart *A. dybowskii* is set off from all the rest of asellids and whether there are not any allied species occurring beyond the limits of Baikal. A close survey of the characters of all the *Asellidae* hitherto described shows that the above-mentioned diagnosis of the subgenus *Mesoasellus* may be well applied to both species *Caecidotea kawamurai* Tattersall from caves of Japan ([13]) and *Asellus californicus* Miller from California caves ([9]). In the same subgenus, most probably, belong *Caecidotea akyoshiensis* Uéno. Its females described from caves in Japan have a great deal in common with females *C. kawamurai* ([14]).

The genus *Caecidotea* is certainly not worth being recognized as independent and is to be united with the genus *Asellus*. This was pointed out by Forbes ([6]) as early as 5 years after the description of *Caecidotea* had been rendered by Packard ([10]), and recently it was finally established by Miller ([9]). If the species listed under genus *Caecidotea* be arranged in groups according to the characters used as a basis for the differentiation of genus *Asellus* into subgenera, the major part of them should be included into the subgenus *Conasellus*. Only *C. kawamurai* and, probably, *C. akyoshiensis* should be referred together with *A. californicus* and *A. dybowskii* to the subgenus *Mesoasellus*, while the taxonomic position of *C. nickajackensis* Packard, *C. richardsonae* Hay and *C. smithii* Ulrich remains unclarified on account of their entirely inadequate description. While examining at present the ranges of distribution of the subgenera *Asellus* enumerated herein, note should be taken that the subgenus *Asellus* occurs eastward of the Rocky Mountains, whereas west of them there are only two species known in North America—*A.* (*M.*) *californicus* Miller and *A. tomalensis* Harford ([15]), whose systematic position has not been ascertained more precisely.

The present distribution of the subgenus *Mesoasellus* appears to be as follows: great depths of the Baikal (*A. dybowskii*), caves in Japan (*A. kawamurai* and *A. akyoshiensis*) and caves in California. The disrupted area of distribution of the subgenus, as well as the nature of habitat of the species it comprises point undoubtedly to the great antiquity of *Mesoasellus*.

Similar relationships are exhibited by some other invertebrates of Baikal. Thus, for example, the species of genus *Epischura* (*Copepoda Calanoida*) are known from the Baikal, lakes of the Far East (lake Khanka, Kamchatka) and North America. The leech *Torix baicalensis* stands close to two Far Eastern species (from Tonkin and China) and to the American genus *Microbdella* with one species *M. biannulata*. All these forms should be regarded as ancient Tertiary relicts.

As already indicated above, there is marked similarity between the subgenera *Mesoasellus* and *Asellus* s. str. Most probably, this similarity is not a casual one. On previous occasions I have already pointed out that *Asellus* s. str. is scattered in detached areas; it is spread along the eastern coast of Asia and over Europe and does not occur in Siberia ([3]). The habitat of *Mesoasellus* is partly in Siberia (Baikal), partly overlaps the eastern territory of the habitat of *Asellus* s. str., and also invades the western part of North America, where *Asellus* s. str. does not occur at all. Chappuis inclines

to the view that *Asellus* s. str. might have originated in Siberia (4), and his hypothesis seems plausible. Taking into consideration the affinity between *Mesoasellus* and *Asellus* s. str., one may venture to suggest that the latter subgenus was derived from the former, or from allied forms, i. e. arose in Eastern Siberia, the home of a number of fresh-water groups, e. g. many *Trichoptera*, which are in Europe likewise immigrants from the North East (3). This may incidentally be substantiated by the fact that among species of the subgenus *Asellus* s. str. the Transcaucasian *A. monticola* Birst. and Far Eastern *A. hilgendorfi* Bov. have one feature in common, and a primitive one at that, distinguishing them from the western *A. aquaticus*, namely the straight outer margin of the exopod of the first pleopod ♂. The same feature is distinctive of *Mesoasellus* as well.

On the other hand, some characteristics (the armature of the first maxilla, the structure of the distal pleopods, the shape of the epimera, etc.) warrant the approximation of *Mesoasellus* to *Baicaloasellus*. True enough, the ties of kinship between these subgenera bear much less distinction than those between *Mesoasellus* and *Asellus* s. str., but at any rate, *Baicaloasellus* is more remote from the remaining subgenera than from *Mesoasellus*. The degree of development of the epimera and uropods which Alpatov has used as a basis for comparing of Baikal *Asellidae* to North American ones, varies greatly within each subgenus and is of minor importance as a taxonomic character. Therefore, from a modern viewpoint there is no ground for approximating the American and Baikal (*Baicaloasellus*) asellids to each other. The *Baicaloasellus* species should be considered as aberrant forms, adapted to the specific conditions of the shallow waters of Baikal, probably linked with *Mesoasellus* by descent.

Thus, to *Asellidae* may well apply the views advocated by Berg in regard to the origin of the Baikal fauna (2), whereby *Baicaloasellus* is to be referred to the first group of Berg, i. e. to the form «which evolved in the Baikal proper in the course of its long geological history», while *Mesoasellus*, to the second group, composed of the «remains of the Upper Tertiary fresh-water fauna of Northern Asia».

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*EXPERIMENTAL MORPHOLOGY*

## CONTRIBUTION TO THE SPECIES SPECIFICITY IN THE LENS-FORMING PROPERTIES OF THE EYE ANLAGE

By V. V. POPOV

*(Communicated by I. I. Schmalhausen, Member of the Academy, 25. VII. 1939)*

In 1937 we published in collaboration with Kislov, Nikitenko and Chanturishvili a preliminary note, and in 1938 a detailed article on the lens-forming properties of the body epithelium of some Mid-Russian amphibians unstudied in this respect. The properties of this epithelium were studied by transplanting under it the optic cup in *Bufo viridis*, *Pelobates fuscus*, *Bombina bombina* and *Triton cristatus*.

It was found that the formation of the lens and of foreign epithelium proceeds most readily in *Pelobates* (easier than in any of the species previously studied), while it is achieved with greatest difficulty in *Bufo viridis* (even more so than in *Bombina*, *Rana arvalis* and *R. esculenta*). It was shown subsequently([11]) that upon transplantation of small bits of body epithelium of *Bufo viridis*, *Bombina bombina*, *Rana arvalis* and *Rana esculenta*, marked for sake of accuracy with carmin powder, onto the depression of the optic cup of *R. esculenta* embryos to replace the preliminary removed lens, the implants invariably transform into lenses. Additional evidence was thus obtained ([6–10]) to illustrate the value of the method of intraocular transplantations as a means to facilitate a most complete expression of the lens-forming properties of the eye rudiment; moreover, my latest unpublished data have shown this to be true of the adult eye.

In 1938 there appeared a paper by Lazarev which had been reported by him long before its publication. Lazarev showed that body epithelium of *Bufo viridis* fails to form a lens in those cases only when it is lined with eye rudiments of the same species, whereas under the influence of the eyecup of *B. bufo* the same epithelium invariably shows lens-formation. Lazarev had no recourse to the new method of intraocular transplantations.

Thus, Lazarev's data are at variance with those cited above. While according to Popov, Kislov, Nikitenko and Chanturishvili the lack of lens induction in the body epithelium of *Bufo viridis* is exclusively due to the properties of the epithelium itself, Lazarev's findings show that this phenomenon depends only on the morphogenetic inferiority of the optic cup of *B. viridis* as compared with that of *B. bufo*. It should, however, be pointed out that Lazarev's data do not seem conclusive enough as far as we can judge by his figure which obviously illustrates the most demonstrative case. This figure shows indeed a quite isolated lens, so that, strictly speaking, it is not quite legitimate to attribute its origin to the epithelium.

The present study was largely influenced by that of Lazarev. It is essentially similar to the preceding one ([11]) except the direction of the trans-

plantations whereas in the preceding study we practiced almost exclusively hetero- and xenoplastic transplantations of bits of body epithelium onto the depression of the eyecup; in the present study only homoplastic transplantations were made.

The purpose of the present work was to ascertain by means of intraocular transplantations, the lens-forming capacities of the eye anlage in different species, especially in *Bufo viridis*. As mentioned above, in the preceding publication attention was focused exclusively on the lens-forming capacity of the epithelium of the same species.

Conclusive evidence was obtained to show that the eyecup of all the species in question, *Bufo viridis* inclusively, is capable of converting into a lens the epithelium fragment implanted onto its depression. That the lenses are actually originating from the implants is evidenced by the invariable presence in them of carmin marks. Preserved implants always showed lens-formation, while their extrusion from the eyecup was of rather infrequent occurrence.

It thus follows that the eye rudiment of *Bufo viridis* is a perfect lens inductor and that Lazarev's interpretation of the results of his experiments is incorrect. It may be suggested that owing to the small size of the cup the old method of transplanting the eye ridiment under the body epithelium or the epithelium on the eye rudiment, does not ensure a perfect contact of the latter with the epithelium, this being actually the only cause of the failure of lens induction. Some indications as to the absence of a sufficiently close contact between the eyecup of *B. viridis* and the epithelium will be found in our previous study([13]).

The results obtained in the present study do not support Lazarev's view as to species specificity of the lens-forming action of the eye rudiment in *B. viridis* and *B. bufo*. It will be noted that Lazarev comes to a far reaching and poorly grounded conclusion to the effect that the eye rudiments of all the amphibians in general differ from one another in their lens-forming properties. That is to say, in his view the action of the eye anlage on the epithelium is definitely species specific. However, literary data seem rather to speak against the existence of such a specificity than to support it ([1], [2], [4], [5], [12]). A somewhat isolated position is occupied only by data of Popov, Kislov, Nikitenko and Chanturishvili (l. c.), who report that after transplantation of the eyecup of *Pelobates fuscus* under the body epithelium of *Rana esculenta* embryos, the host epithelium has formed lenses which greatly resembled in all their characters a lens of the donor, rather peculiar in its differentiation, i. e. of *Pelobates*. These few experiments which seem to support Lazarev's generalization require, however, a most careful revision on a more extensive material.

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*EXPERIMENTAL MORPHOLOGY*

# COMPARATIVE ANALYSIS OF SOME OF THE MUSCLES OF THE HIND EXTREMITY OF SHEEP

By R. M. SHAKHUNIANTZ

*(Communicated by I. I. Schmalhausen, Member of the Academy, 26. VI. 1939)*

So far very little research has been done on the evolution of the muscular system of sheep. All that is to be found on this subject in literature is of a fragmentary nature and gives no precise morphological analysis. In this respect mention should be made of the fundamental work by John Hammond(1).

The present research is a first step towards the solution of the problem of the evolution of the muscular system of sheep. In the abscence of a detailed study of the muscular system of sheep we had to begin our investigation with a preliminary study of the separate muscles and particularly of the muscles of the hind extremity of sheep, so as to pass onto an immediate elucidation of the problems connected with the evolution of the entire muscular system.

We have made a morphological analysis of individual muscles of the hind extremity of six sheep, four of the karakul breed and two of the northern short-tailed breed. We have chosen our material from among these breeds because of the ease with which it could be obtained. The karakul sheep were of different mutton qualities and age (some were three and some five-year-old), with and without horns. This offered us the possibility of comparing our data with those of Hammond who delt with other breeds.

The preliminary data obtained as a result of our study of the femoral muscles may serve as an indication of the development of one or the other of the muscles. Although all the femoral muscles have been investigated by us, we shall only dwell on those for which the most accurate data were obtained.

Our study of the muscles of the hind extremity of karakul sheep has shown that certain muscles are more developed in one sex than in the other. Our preliminary data have shown that the most developed muscles of an akgyul ram, five years of age, of a body weight above the average are: m. glutaeus medius, m. glutaeus superf. and m. biceps femoris, m. tensor fasciae latae; however, in ewes of about the same age and body weight these muscles are much less developed. In proportion to body weight these muscles in a ram of the age of five years are as follows: m. glutaeus medius, 0.46%; m. glutaeus superf. and m. biceps femoris, 0.58%; m. tensor fasciae latae, 0.17%. The proportions in a dam are: m. glutaeus medius, 0.39%; m. glutaeus superf. and m. biceps femoris, 0.53%; m. tensor fasciae latae, 0.16%.

Approximately the same proportion is to be observed in the development of the m. glutaeus medius, m. glutaeus superf. and m. biceps femoris,

m. tensor fasciae latae in ewes and rams of the northern short-tail breed, provided they are of similar body weight and age. Indeed, in a ram of three years of age and of average body weight the m. glutaeus medius equalled 0.40%, the m. glutaeus superf. and the m. biceps femoris, 0.61%, the m. tensor fasciae latae, 0.18%, while in a ewe the m. glutaeus medius equalled 0.32%, the m. glutaeus superf. and the m. biceps femoris, 0.56%, and the m. tensor fasciae latae, 0.16%.

Our preliminary data show that the development of the m. glutaeus medius, the m. tensor fasciae latae, the m. glutaeus superf. and the m. biceps femoris, the m. semitendinosus, the m. semimembranosus, and the m. adductor differs according to age. Thus, for instance, in a three-year-old karakul ewe of the akgyul type the m. glutaeus medius equalled 0.52%, the m. tensor fasciae latae, 0.19%, while in a ewe of five years of age the proportions were: m. glutaeus medius, 0.39%, m. tensor fasciae latae, 0.16%. The three-year-old ewes were of average body weight, while the five-year-old ewes had a body weight above the average. This allows us tentatively to draw the conclusion that the proportion of the m. glutaeus medius and the m. tensor fasciae latae in the main depends on age.

The development of the m. glutaeus medius, the m. tensor fasciae latae, the m. glutaeus superf. and m. biceps femoris, the m. semimebranosus and the m. adductor evidently depends also on the type of constitution in the various breeds of sheep; this is of special significance for the karakul sheep. Thus, our investigation has shown the following proportion of the muscles in a karakul ram of the akguyl type of the age of five years and of a body weight above the average: m. tensor fasciae latae, 0.17%; m. glutaeus medius, 0.46%; m. semimembranosus, 0.53%; in a ram of the guza-moy type of the age of three and of similar body weight, the proportion was as follows: m. tensor fasciae latae, 0.11%; m. glutaeus medius, 0.19%; m. semimembranosus, 0.28%.

While the m. glutaeus medius, the m. glutaeus superf. and m. biceps femoris and the m. tensor fasciae latae are, as a rule, more developed in the ram than in the ewe (with the exception of the guza-moy type), the m. adductor is, on the contrary, more developed in the ewe than in the ram. Thus, the proportion of the m. adductor in a three-year-old ram of the northern short-tail breed is 0.21%, while in a ewe of the same age it equals 0.26%. This muscle is particularly insignificant in a karakul ram of the guza-moy type at the age of three, its proportion being 0.12%.

These preliminary data show that Hammond's statement to the effect that the muscles of a ram are more developed than those of a ewe is not quite correct, for it is not always in accordance with facts when comparison is made of individual muscles in males and females; the statement is evidently true only in comparisons of the total weight of all the muscles of the thigh of a ram with that of a ewe.

Finally, our preliminary observations allow us to presume that the development and correlation of the various muscles in a ram and ewe depend also on the breed. Thus, for example, in a karakul ram at the age of five the m. semimembranosus is more developed than in a ewe of the same breed and age. This muscle, however, in the northern short-tail breed is equally developed in the ram and in the ewe at the age of three. The m. semitendinosus is almost equally developed in the ram of the guza-moy type and in the karakul ram of the akgyul type notwithstanding the difference in age (the former was three years old, the latter, five).

We have made a study not only of weight indices, but also of the shape and form of the separate muscles. We shall not touch on this aspect of the subject, but deem it necessary to note that the m. glutaeus superficialis is

exceptionally variable in form. Our preliminary investigations also show that the development of the fibres of the m. tensor fasciae latae, the m. glutaeus medius, the m. biceps femoris, the m. semitendinosus, the m. semimembranosus and the m. sartorius is different in sheep of different body weight. Thus, while the fibres of the said muscles are more developed in sheep with an above the average body weight, they are, on the contrary, considerably less developed in sheep with a body weight below the average. An indication of this is the difference in the size of the diameter of these fibres in sheep with a body weight above the average and sheep below the average. Our investigations show that in sheep with a body weight above the average the connective tissues are more developed than in sheep with a body weight below the average.

In addition, a microscopic study of the muscular fibres in sheep has shown that there is a certain difference in the development of the connective tissue as well as in the size of the muscular fibres in the male and in the female. Thus, in the ram of the northern short-tail breed the fibres are large, while the connective tissues are weakly developed and are in the shape of very narrow threads. On the contrary, in the ewe of the same breed the fibres are smaller, while the connective tissues are considerably more developed and have the form of more or less wide and numerous threads.

These preliminary investigations offer tentative data indicating the factors to which attention should be paid in the future when analyzing a large quantity of material.

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*GEOGRAPHY*

# ON VOLGA-URAL DESERT AND SEMI-DESERT SANDS (OBSERVATIONS FROM THE AIR)

By T. YAKUBOV

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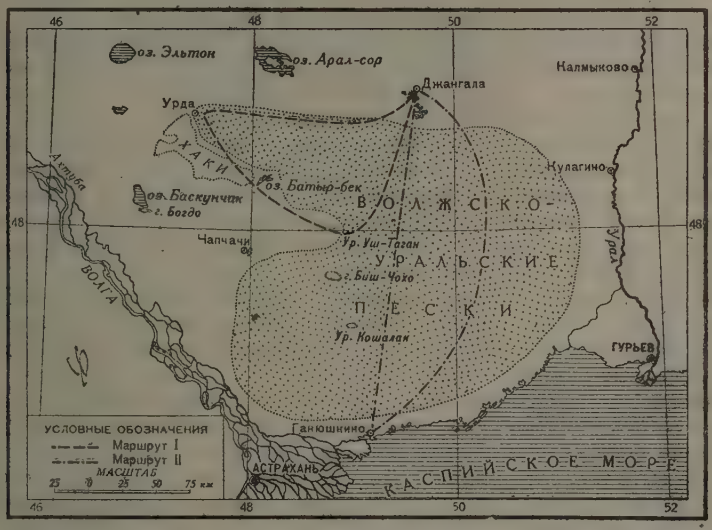
In order to make a study of the less known parts of the Volga-Ural sands our expedition in 1938 undertook several caravan journeys to the desert regions beyond the Volga. Thanks to the assistance given us by the Saratov Institute of Microbiology, Epidemiology and Parasitology, our expedition was able to make two special flights over the Volga-Ural sands (the map). The




flights were made along the following routes*: 1) Djangala—Ush-tagan—Urda—Djangala, and 2) Djangala—eastern part of the sands beyond the Volga—Ganyushkino—Djangala. The length of both air routes totalled about 1000 km.

* The flight and observations on the first route were made by T. F. Yakubov, head of the expedition, and on the second, by M. K. Deulina, geobotanist of the expedition.

The ceiling of our flight averaged one kilometer, and the weather being calm and clear we were able to observe quite distinctly the general configuration of the country and all the changes in landscape on both routes. The absence, however, of landmarks, made it difficult for us to ascertain the location of the observations made. In this respect the first route offered certain advantages, since here we encountered some inhabited localities, though far and few between, such as Urda and Ush-tagan, as well as clearly discernible natural landmarks, such as Aral-sor, the Urda khaki and the ribbon-shaped sands of Naryn. Since these sands have on the whole been very little studied, we believe that our observations from the air which were partly co-ordinated with our overland itineraries will prove of some interest. We are confident that with all their shortcomings our data not only possess a certain scientific significance, but may also serve as material which at least gives a general outline of the Volga-Ural sands.

We give below our observations on each route separately.

## Route 1. Djangala—Ush-tagan—Urda—Djangala (August 14, 1938)

1. Soon after our airplane took off from Djangala we passed over a region, the surface of which represented a combination in almost equal proportion of two elements, islands of sand mounds and *shors*. The sands were in the shape of large elongated banks or ridges, mostly stretching from ENE to WSW and more seldom from NE to SW. The central parts of these stretches of sand were chains of bare sand mounds with their eastern slope lying windward and the western leeward. We have noticed that almost everywhere these sands were surrounded by a comparatively narrow ring of knobby sands overgrown to a greater or smaller extent by vegetation.

Between these sands and the *shors* lay a strip of saline soil marked by the yellowish-orange colour of its peculiar vegetation. Beyond this strip one could clearly observe the bare bottoms of the *shors* with a white cover of salt, some of them being under water. It is interesting to note that the *shors* showed a great diversity of forms: from elongated nearly circular to oval, sometimes with a few branchings diverging from the «main stem». The latter forms seemed to predominate and were in a chain stretching in the latitudinal direction, too. One gained the impression that a *shor* or a system of *shors* with the adjoining saline soils formed a continuation of another *shor* mostly divided from each other by the above-mentioned sands.

Apart from these two main elements of the ground, here and there, between the sands and the depressions of saline soils and *shors*, one may observe dark-grey flats; these are very likely sand soils which have not been affected by the process of breaking up and deflation.

2. Further on, at the latitude of the Aral-sor khaki, the sands which here too are of an isolated character, considerably increase in area. Here they are more clearly defined in the shape of elongated banks and ridges stretching from ENE to WSW. The central parts of these isolated sands form chains of sand hills surrounded by a narrow ring of knobby sands. The area of the sand hills here is somewhat larger than in the previous region. This especially strikes the attention in the western part of the field of observation and in particular in the section where sands and steppe are in contact. To judge by the roads and huts to be observed here, this part is more inhabited than the eastern part.

The *shors* are less in evidence here than in the previous region and the sands obviously predominate. In this respect the western section of the sands adjoining the system of the Aral-sor khaki forms an exception. Here, the

number and size of the *shors* are obviously on the increase. Here as in the previous region, the *shors* are mostly bordered by a narrow zone of saline soils.

Apart from the isolated sands and the saline soil and *shor* depressions, the area of the dark-grey flats in this region perceptibly increases. These flats have an oblong form and run parallel to the saline soil and *shor* depressions forming a transition from the latter to the isolated areas of sand hills and knolls. Judging by the observations made on land in the region of the Aral-sor knaki, it may be presumed that these flats are sand plains covered with wormwood and cereal growth.

Somewhat more to the South, with the approach of the Naryn sands when the *shors* disappear altogether, these dark grey flats lying between the isolated sands acquire a yellowish-green colour, evidently from the cereal grasses that cover them. These are, probably, the ashiki, sand plains, of which a great many are to be found in the region of the Naryn sands.

3. Finally, the third region, that of the Naryn sands, which sharply differs from the two others. These sands consisting of sand knolls and ashiki, i. e. sand plains, are clearly discernible from the air, stretching like a ribbon from NE to SW.

The transition from the landscape of the two previous regions to that of the Naryn sands is gradual and of a peculiar nature. The peculiarity of this transition is especially salient in the contact zone of the two described regions, where the sand hills and knolls form a continuation of the ribbon of sand knolls of Naryn torn into separate little massive groups. The transition is not so clearly defined on the side of the sand plains which, in the contact zone, branch off into numerous winding «arms», a considerable number of them stretching from NE to SW.

Sand hills are hardly to be found here at all. *Shors* in the shape of small spots are very rarely met with on the sand plains. On the sand knolls of Naryn, particularly on the outlying part of the latter, trees may clearly be observed.

## Route 2. Djangala—Eastern part of the sand in the region beyond the Volga—Ganyushkino—Djangala (August 15, 1938)

1. South-east of Djangala stretch dark grey plains, evidently sandy land overgrown with white wormwood and rarely interspersed with sand hill areas which on the periphery are bordered by a narrow zone of sand knolls half overgrown with vegetation. Moving a little forward one may observe an ever larger number of sand hills; *shors* begin to make their appearance and soon the dark-grey plain is thickly dotted with them.

2. Further still, the isolated sands merge covering large areas with sand knolls predominating. Among these knolls sand hills are to be found in small massive groups. In the zone of the sand hills the latter are seen to stretch in chains running North to South or NNE to SSW. Here the sand areas alternate with strips of dark-grey flats lying latitudinally. Very seldom on these dark-grey flats small *shors* may be observed, now of a circular and now of an oval or oblong shape, sometimes filled with water.

3. Further on, the sand knolls predominate in the landscape. Among these sands one may clearly observe areas either scantily or thickly covered with vegetation. The thickly overgrown areas are evidently sand plains or ground with low sand knolls. The area under sand hills is quite insignificant. The monotony of the landscape of this region is seldom broken by small, mostly dry *shors* which in certain parts are concentrated in small groups.

4. About half way between Djangala and Ganyushkino there is a considerable area of sand hills. While in the previous regions sand hills were rarely met with, here their number almost equals that of the sand knolls. Apart from the presence of sand hills, the characteristic feature of this region is the large number of *shors* which are of different shape and size and run in different directions. The *shors* lying almost latitudinally are long and have the shape of narrow arms. Among them are large circular *shors* either filled with water or dry. The surface of the dry *shors* is of a reddish-rose colour with white spots of faded salt. Apart from the sands and *shors*, the landscape here is marked by flats of various size alternating with the other elements of the landscape previously described.

In this region our attention was for the first time drawn to small dark-green spots scattered singly or in groups among the sands and also in the shape of chains on the borders of the saline soils and less frequently on the borders of the *shors*. As we have discovered later when crossing these sands on our overland journey, these spots were small shrubs of tamarisk or cumulus sands with tamarisk and nitre-bush.

5. As we approached the sea, the areas of sand hills grew in number. The sand hill chains here stretch almost meridionally. Their weathered slopes face WNW. The dark-grey flats here are small and mainly divide the areas of sand hills. As our observations on our overland journey have shown, these sections are covered with salt vegetation which is also developed on the sand plains and partly on the depressions of the low sand knolls.

There is only a small number of *shors* here which are usually small in size. However, as they approach the seashore where they appear in the shape of narrow canals running almost latitudinally, they increase in size. Apart from the large number of sand hills, the peculiar feature of this region is the abundance of green tamarisk spots which liven up the dull grey colour of the landscape. The tamarisk shrubs are located in the hollows of the sand knolls which surround the sand hill banks. Evidently, these shrubs were planted by man to serve the purpose of protection from the sands.

6. The last region, on the Caspian coast, is a region of saline soils cut by old channels and canals with solitary areas of sand hills and knolls. The old channels and canals, filled with water, are mostly fringed by a narrow border of vegetation. The dried up old channels are mostly overgrown with vegetation.

On the basis of the above material we may draw some conclusions of preliminary and general nature.

1. The Volga-Ural sand land, despite the views still entertained, is marked by a great variety of landscape which is the outcome of a long process of development under the effect of natural and historical factors and of the activity of man.

2. In their present state the Volga-Ural sands form a sufficiently complex combination of various elements such as sands, *shors*, saline soils, steppe areas, etc., the proportion of each of them varying in the various regions.

3. With all the variety of the landscape of this territory, sands are the predominant feature, all the other elements of the landscape possessing only a subordinate significance.

4. The sands which constitute the main element in the landscape show a certain regularity in that they increase in area as we proceed from North to South. At the same time while in the northern parts there is a predominance of the various types of sand knolls, in the southern parts there is a considerable number of hilly and knobby sands. The islands of hilly sands in the northern parts have evidently been formed as a result of the wasting of the pasture land.

5. The *shor* and saline soil depressions are almost everywhere more or less evenly distributed, but in certain areas owing to local conditions (geological structure, configuration, etc.) they are to be found in greater numbers (the *shors* in the region of the Kamysh-Samara lakes, the khaki of the Aral-sor, the Urda khaki, etc.).

6. The observations made on the general relief of the sands and the other elements of the landscape (*shors*, saline soil depressions, plains) and also on their regular lie, clearly show that the present territory of the Volga-Ural sands constitutes a typical delta plain or a merger of several former deltas.

7. It may be assumed that the islands of sands and sandy soil which almost everywhere have been changed by deflation processes, are nothing else but the remains of erosion, while the *shor* and saline soil depressions are old beds of the ancient alluvial channels, their present view conditioned by way of general climatic changes, the lowering of the erosion base, etc.

8. The regular latitudinal lie of the sand islands, banks, ridges, *shors*, saline soil depressions throughout the Volga-Ural sand area enables us to presume that the flow of the water channels was evidently in a west-south-west and south-west direction with a tendency towards the present Volga-Aktyubinsk valley.

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